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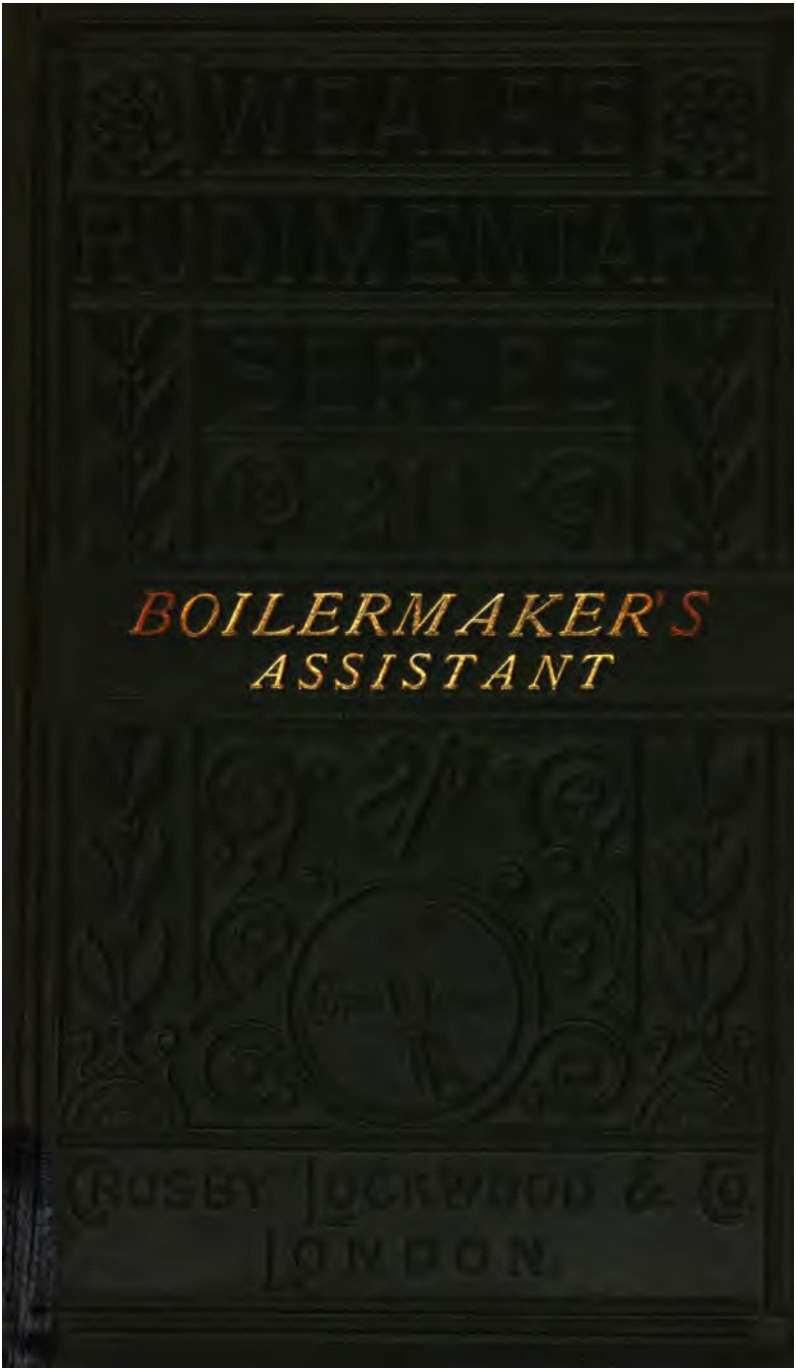

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PREFACE.

Being myself a working boilermaker I may be credited with a knowledge of the needs of boilermakers with respect to operations of drawing, templating, and calculating. Foremen boilermakers are not supposed to impart instruction in these operations to any but those apprentices under them in whom they may take an interest. At the same time, the educated foreman has a right to expect the journeyman to have sufficient knowledge of his work. I have experienced the want of a book such as I flatter myself is formed by these collected notes. They contain many things equally simple and necessary to a boilermaker, and which every boilermaker should know, in order that he may go about his work in a systematic and business-like manner, and not by guesswork and makeshift.

I could not find any one book (within the reach of my wages to purchase) sufficiently comprehensive and practical to be at once useful to the apprentice as well as to the journeyman, and devoted simply to the craft of the boilermaker, without the use of those mathematical terms which usually perplex and turn away from the study of such works many who would otherwise learn. I have therefore, herein, arranged for publication what was once a private note-book of rules for my own use. I know that the generality of men cannot answer all questions, even in relation to their own trade, just on the spur of the moment. Hence the necessity of a compact work of this sort, which the boilermaker can carry in his pocket, and in which he can find directions and tables for all the templating and calculation required in the course of his work.

In conclusion, I have to express my grateful acknowledgments to Mr. D. Kinnear Clark, whose reputation and writings are known to the whole engineering world, for his kindness in revising my manuscript and suggesting improvements thereto.

JOHN COURTNEY.

NOTE BY THE EDITOR.

I have had pleasure in revising and editing Mr. Courtney's notes, here following. They bear the impress of good practice and experience; and, simple and unpretending as they are, they will come home to the understandings of thoughtful workmen. The problems, which have been selected with judgment, and the rules, which are expressed with simplicity, will be directly useful to the practical boilermaker, and will supply just what he requires for calculating his quantities, constructing his diagrams, and shaping his templates. At the same time, he will be enabled, when called upon to do so, to proportion the rivet-joints and also to settle the dimensions of boilers, according to the pressure at which they are to work, and the power that is to be required of them.

D. K. CLARK.

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THE BOILERMAKER'S ASSISTANT.

CHAPTER I.

DEFINITIONS AND USEFUL NUMBERS.

ARITHMETICAL SIGNS USED IN THIS BOOK.

$+$ Plus, or more, the sign of addition, as $2+2=4$.

$-$ Minus, or less, the sign of subtraction, as $4-2=2$.

$\times$ signifies multiplied into or by, as $3\times 3=9$.

$\div$ signifies divided by, as $10\div 5=2$.

$=$ signifies equality, or equal to, as $4+4=8$.

$: \; :: \; :$, the sign of proportion, as $2:4::3:6$; which reads thus: as 2 is to 4 so is 3 to 6.

$\surd$, the sign of the square root, as $\sqrt{49}=7$; that is 7 is the square root of 49, or 7 is the number which, if multiplied by itself, produces 49.

7^2 means the square of 7, or that 7 is to be squared or multiplied by itself. The square of any number is the product of the number multiplied by itself.

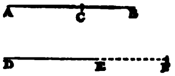
7^3 means the cube of 7, or that 7 is to be multiplied by 7, and again by 7. The cube of any number is the product of that number multiplied by itself, and again by itself.

61

SQUARE MEASURE AND CUBIC MEASURE.

144 square inches = 1 square foot.
9 square feet = 1 square yard.
1,728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.

DEFINITIONS OF TERMS WHICH ARE EMPLOYED IN THE FOLLOWING RULES.



Figs. 1 and 2.

A Point has a position without magnitude, as at C, Fig. 1.

A Line has length without breadth, as D E, Fig. 2.

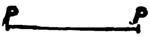


Fig. 3.

A Right Line is the shortest distance between any two points, P P, Fig. 3.

Fig. 4.

A Superficies has length and breadth only. Fig. 4.

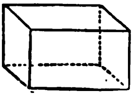


Fig. 5.

A Solid has length, breadth, and thickness. Fig. 5.

An Angle is the opening of two lines having different directions, and is either Right, Acute, or Obtuse.

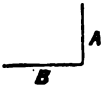


Fig. 6.

A Right Angle is made by a line being drawn perpendicular to another, as in Fig. 6.

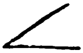


Fig. 7.

An Acute Angle is less than a Right Angle. Fig. 7.

An Obtuse Angle is greater than a Right Angle. Fig. 8.

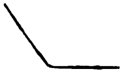


Fig. 8.

A Triangle is a figure bounded by three straight lines. Figs. 9, 10, 11.

An Equilateral Triangle is a Triangle of which the three sides are equal to each other. Fig. 9.

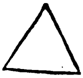


Fig. 9.

An Isosceles Triangle has two of its sides equal. Fig. 10.

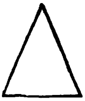


Fig. 10.

A Scalene Triangle has all its sides unequal. Fig. 11.

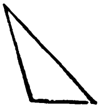


Fig. 11.

A Right-angled Triangle has one Right Angle. Fig. 12.

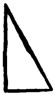


Fig. 12.

A Square is a 4-sided figure having all its sides equal, and all its angles Right Angles. Fig. 13.

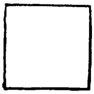


Fig. 13.

A Rectangle is a four-sided figure, having its angles Right Angles, and of which the length exceeds its breadth. Fig. 14.

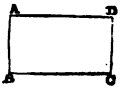


Fig. 14.

307 = Gallons.
= Gallons.
32 = Gallons.
= Gallons.
= Side of
= Diam.
of equ
= Area of
= Circum
= Gallon
= Gallon
Tons.
Pound

D FE

CHAPTER II.

MENSURATION.

To find the circumference of a circle when the diameter is given.—Multiply the diameter by 3·1416; the product is the circumference.

A common method of calculating the circumference is to multiply the diameter by 3, and add $\frac{1}{7}$ of the diameter to the product. The sum is the circumference, very nearly. Or, what amounts to the same thing, multiply the diameter by 22, and divide the product by 7.

Another method of finding the circumference is to multiply the diameter by 3, and add $\frac{9}{16}$ inch to the product for every foot-length in the product. The reason for adding $\frac{9}{16}$ inch for each foot of the product, is, that it is the same in effect as the addition of $\frac{1}{7}$ of the diameter. As the product is equal to three times the diameter, the addition to be made per foot of product should be only a third of the addition per foot of diameter; that is, instead of $\frac{1}{7}$ of the diameter, the addition is $\frac{1}{3}$ of $\frac{1}{7}$, or $\frac{1}{21}$ of the product, which is at the rate of $\frac{9}{16}$ inch per foot of the product.

To find the diameter of a circle when the circumference is given.—Multiply the length of the circumference by the decimal ·3183; the product is the diameter.

Or, divide the circumference by 3·1416; the quotient is the diameter.

Or, multiply the circumference by 7, and divide the product by 22; the quotient is the diameter, very nearly.

To find the area of a circle.—Square the diameter—that is to say, multiply the diameter by itself, say, in inches—and multiply the product by the decimal ·7854. The product is the area of the circle in square inches.

To find the length of an arc of a circle.—From 8 times the chord, A D, Fig. 17, of half the arc A D E, subtract the chord of the whole arc, A E, and divide the remainder by 3. The quotient is the length of the arc, nearly.

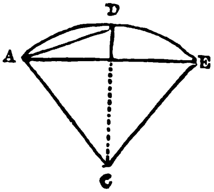


Fig. 17.

To find the diameter when the chord of an arc and the versed sine are given.—Divide the square of half the chord by the versed sine, and to the product add the versed sine. The sum is the diameter.

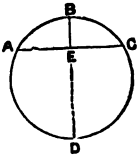


Fig. 18.

Note.—The versed sine is the height of the arc.

To find the area of a segment of a ring.—Multiply half the sum of the bounding arcs by their distance apart; the product is the area. Thus, let the arc A X D be 90

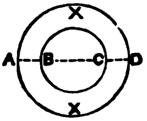


Fig. 19.

inches long, and the arc B C 40 inches long, and the distance A B or C D 18 inches long; then $90'' + 40'' = 130$; and $130 \div 2 = 65$; and $65 \times 18'' = 1170$ square inches, the area.

To find the area of a segment of a circle.—To $\frac{2}{3}$ of the product of the chord A B and versed sine C D of the segment, add the cube of the versed sine divided by twice the chord; and the sum is the area, nearly. Thus—

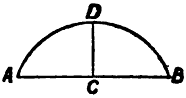


Fig. 20.

Given the chord A B as 20 inches, and the versed sine 3 inches; required the area. $20 \times 3 = 60$; and $60 \times 2 \div 3 = 40$. Then 3 inches cubed $= 3 \times 3 \times 3 = 9 \times 3 = 27$; and $27 \div (20 \times 2) = {\cdot}675$; and ${\cdot}675 + 40 = 40{\cdot}675 =$ area nearly.

When the segment is greater than a semicircle, find the area of the remaining segment and deduct it from the area of the whole circle, the remainder is the area of the segment.

To find the area of a sector of a circle.—Multiply half the length of the arc by the radius of the circle. The product is the area of the sector. See Fig. 17.

To find the circumference of an ellipse.—Add the two diameters together; divide the sum by 2, and multiply the quotient by $3{\cdot}1416$. Or, multiply the sum of the two diameters by $1{\cdot}5708$. The product, in either process, is the circumference nearly. Thus—What is the circumference of an ellipse of which the

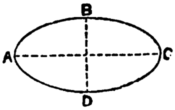


Fig. 21.

diameters are 10 and 14? $14 + 10 = 24$; and $24 \times 1{\cdot}5708 = 37{\cdot}6992$: or, $10 + 14 = 24$; and $24 \div 2 = 12$; and $12 \times 3{\cdot}1416 = 37{\cdot}6992 =$ the circumference of the ellipse.

To find the area of an ellipse.—Multiply the two diameters together, and multiply the product by ·7854. The final product is the area.

To find the area of a square.—Multiply the length of one side by itself, or square the side. The product is the area. For example, a square has each side 12 inches long; what is the area? $12 \times 12 = 144$ square inches is the area of the square.

To find the area of a rectangle.—Multiply the length by the breadth; the product is the area. For example, a rectangular plate is 24 inches long and 12 inches wide; what is the area? $24 \times 12 = 288$ square inches.

To find the cubic content of a rectangular or cubical body.—Multiply the length by the breadth, and multiply the product by the depth. The last product is the cubic content. For example, a box or a cistern is 5 feet long, 2½ feet wide, and 3 feet deep; what is the cubic content? 5 feet multiplied by 2½ feet makes an area of 12½ square feet; and 12½ multiplied by 3 is equal to 37½ cubic feet.

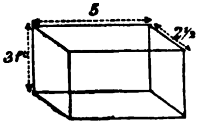


Fig. 22.

To find the cubic content of a square-ended cylinder.—Find the area of one end by the rule for the area of a circle, and multiply the area by the length. The product is the cubic content of the cylinder.

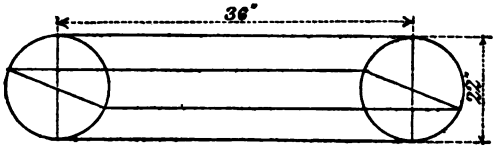


Fig. 23.

Note.—The dimensions are to be taken all in inches or all in feet. The square measure and the cubic measure, correspondingly, will be in inches or in feet.

Example.—A cylinder is 22 inches in diameter and 36 inches in length; what is the cubic content?

```
 22 inches.        ·7854
 22                  484
 ——               ——————
 44                31416
44                62832
———              31416
484              ———————
═══              38·01336 square inches, area of the end.
                       36
                 ————————
                 22808016
                11404008
               ——————————
               1368·48096 cubic inches, solid content.
               ══════════
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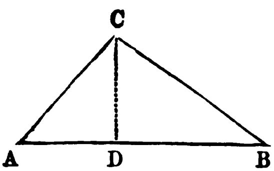


Fig. 24.

To find the area of a triangle.—Multiply the length of the base A B by the perpendicular height C D, and divide the product by 2. The quotient is the area of the triangle.

When the triangle is equilateral, or equal-sided, the area may be calculated by squaring the side, dividing the square by 4, and multiplying by 1·732.

To find the cubic content of a sphere.—Multiply the cube of the diameter by the decimal ·5236; the product is the cubic content. For example, let the diameter be 12 inches. The cube of 12, or $12 \times 12 \times 12 = 1728$, and $1728 \times \cdot 5236 =$ 904·8 cubic inches.

To find the content of a segment of a sphere.—Square the radius, or half diameter, of the base, and multiply the square by 3. To the product add the square of the height of the segment, and multiply the sum by the height and by the decimal ·5236. The product is the content of the segment.

To find the content of a frustum of a cone.—Square the diameter of each end, and multiply one diameter by the other; add together the two squares and the product, and multiply the sum by the height of the frustum and by ·2618. The final product is the content.

To find the content of a frustum of a square pyramid.—Add together the areas of the two ends and the product of the lengths of side of the ends; multiply the sum of the height, and divide the product by 3.

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1	$3\frac{1}{8}$	$4\frac{3}{4}$	$14\frac{7}{8}$	$8\frac{1}{2}$	$26\frac{5}{8}-\frac{1}{16}$
$1\frac{1}{8}$	$3\frac{1}{2}$	$4\frac{7}{8}$	$15\frac{1}{4}$	$8\frac{5}{8}$	$27\frac{1}{16}$
$1\frac{1}{4}$	$3\frac{7}{8}$	5	$15\frac{5}{8}-\frac{1}{16}$	$8\frac{3}{4}$	$27\frac{3}{8}-\frac{1}{16}$
$1\frac{3}{8}$	$4\frac{1}{4}$	$5\frac{1}{8}$	$16\frac{1}{16}$	$8\frac{7}{8}$	$27\frac{7}{8}$
$1\frac{1}{2}$	$4\frac{5}{8}-\frac{1}{16}$	$5\frac{1}{4}$	$16\frac{1}{2}$	9	$28\frac{1}{4}$
$1\frac{5}{8}$	$5\frac{1}{16}$	$5\frac{3}{8}$	$16\frac{7}{8}$	$9\frac{1}{8}$	$28\frac{5}{8}$
$1\frac{3}{4}$	$5\frac{3}{8}-\frac{1}{16}$	$5\frac{1}{2}$	$17\frac{1}{4}$	$9\frac{1}{4}$	$29\frac{1}{16}$
$1\frac{7}{8}$	$5\frac{7}{8}$	$5\frac{5}{8}$	$17\frac{5}{8}$	$9\frac{3}{8}$	$29\frac{3}{8}-\frac{1}{16}$
2	$6\frac{1}{4}$	$5\frac{3}{4}$	$18\frac{1}{16}$	$9\frac{1}{2}$	$29\frac{3}{4}-\frac{1}{16}$
$2\frac{1}{8}$	$6\frac{1}{2}$	$5\frac{7}{8}$	$18\frac{3}{8}-\frac{1}{16}$	$9\frac{5}{8}$	$30\frac{1}{8}-\frac{1}{16}$
$2\frac{1}{4}$	7	6	$18\frac{3}{4}-\frac{1}{16}$	$9\frac{3}{4}$	$30\frac{5}{8}$
$2\frac{3}{8}$	$7\frac{3}{8}-\frac{1}{16}$	$6\frac{1}{8}$	$19\frac{1}{8}-\frac{1}{16}$	$9\frac{7}{8}$	$31\frac{1}{16}$
$2\frac{1}{2}$	$7\frac{7}{8}$	$6\frac{1}{4}$	$19\frac{5}{8}$	10	$31\frac{3}{8}$
$2\frac{5}{8}$	$8\frac{1}{4}$	$6\frac{3}{8}$	$20\frac{1}{16}$	$10\frac{1}{8}$	$31\frac{3}{4}-\frac{1}{16}$
$2\frac{3}{4}$	$8\frac{1}{2}$	$6\frac{1}{2}$	$20\frac{3}{8}$	$10\frac{1}{4}$	$32\frac{1}{8}-\frac{1}{16}$
$2\frac{7}{8}$	9	$6\frac{5}{8}$	$20\frac{3}{4}-\frac{1}{16}$	$10\frac{3}{8}$	$32\frac{1}{2}-\frac{1}{16}$
3	$9\frac{3}{8}$	$6\frac{3}{4}$	$21\frac{1}{8}-\frac{1}{16}$	$10\frac{1}{2}$	$32\frac{7}{8}-\frac{1}{16}$
$3\frac{1}{8}$	$9\frac{3}{4}-\frac{1}{16}$	$6\frac{7}{8}$	$21\frac{5}{8}$	$10\frac{5}{8}$	$33\frac{1}{4}-\frac{1}{16}$
$3\frac{1}{4}$	$10\frac{1}{8}-\frac{1}{16}$	7	22	$10\frac{3}{4}$	$33\frac{3}{4}$
$3\frac{3}{8}$	$10\frac{1}{2}-\frac{1}{16}$	$7\frac{1}{8}$	$22\frac{3}{8}$	$10\frac{7}{8}$	$34\frac{1}{8}$
$3\frac{1}{2}$	11	$7\frac{1}{4}$	$22\frac{3}{4}$	11	$34\frac{1}{2}-\frac{1}{16}$
$3\frac{5}{8}$	$11\frac{3}{8}$	$7\frac{3}{8}$	$23\frac{1}{8}$	$11\frac{1}{8}$	$34\frac{7}{8}-\frac{1}{16}$
$3\frac{3}{4}$	$11\frac{3}{4}$	$7\frac{1}{2}$	$23\frac{1}{2}-\frac{1}{16}$	$11\frac{1}{4}$	$35\frac{1}{2}-\frac{1}{16}$
$3\frac{7}{8}$	$12\frac{1}{8}$	$7\frac{5}{8}$	$23\frac{7}{8}-\frac{1}{16}$	$11\frac{3}{8}$	$35\frac{5}{8}-\frac{1}{16}$
4	$12\frac{1}{2}-\frac{1}{16}$	$7\frac{3}{4}$	$24\frac{1}{4}-\frac{1}{16}$	$11\frac{1}{2}$	$36\frac{1}{16}$
$4\frac{1}{8}$	$12\frac{7}{8}-\frac{1}{16}$	$7\frac{7}{8}$	$24\frac{5}{8}-\frac{1}{16}$	$11\frac{5}{8}$	$36\frac{1}{2}$
$4\frac{1}{4}$	$13\frac{1}{4}-\frac{1}{16}$	8	$25\frac{1}{8}$	$11\frac{3}{4}$	$36\frac{7}{8}$
$4\frac{3}{8}$	$13\frac{3}{4}$	$8\frac{1}{8}$	$25\frac{1}{2}$	$11\frac{7}{8}$	$37\frac{1}{4}-\frac{1}{16}$
$4\frac{1}{2}$	$14\frac{1}{8}$	$8\frac{1}{4}$	$25\frac{7}{8}$	12	$37\frac{5}{8}-\frac{1}{16}$
$4\frac{5}{8}$	$14\frac{1}{2}$	$8\frac{3}{8}$	$26\frac{1}{4}-\frac{1}{16}$	$12\frac{1}{8}$	$38\frac{1}{16}$

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
12¼	38⅜-1/16	16	50¼	19¾	62
12⅜	38¾-1/16	16⅛	50⅝	19⅞	62⅜-1/16
12½	39¼	16¼	51 1/16	20	62¾-1/16
12⅝	39⅝	16⅜	51⅜-1/16	20⅛	63⅛-1/16
12¾	40 1/16	16½	51¾-1/16	20¼	63½-1/16
12⅞	40⅜-1/16	16⅝	52⅛-1/16	20⅜	64
13	40¾-1/16	16¾	52½-1/16	20½	64⅜
13⅛	41⅛-1/16	16⅞	53	20⅝	64¾
13¼	41½-1/16	17	53⅜	20¾	65⅛-1/16
13⅜	42	17⅛	53¾	20⅞	65½-1/16
13½	42⅜	17¼	54⅛-1/16	21	65⅞-1/16
13⅝	42¾-1/16	17⅜	54½-1/16	21⅛	66¼-1/16
13¾	43⅛-1/16	17½	54⅞-1/16	21¼	66¾
13⅞	43½-1/16	17⅝	55¼-1/16	21⅜	67⅛
14	43⅞-1/16	17¾	55¾	21½	67½
14⅛	44¼-1/16	17⅞	56⅛	21⅝	67⅞
14¼	44¾	18	56½	21¾	68¼-1/16
14⅜	45⅛	18⅛	56⅞-1/16	21⅞	68⅝-1/16
14½	45½-1/16	18¼	57¼-1/16	22	69 1/16
14⅝	45⅞-1/16	18⅜	57⅝-1/16	22⅛	69½
14¾	46¼-1/16	18½	58 1/16	22¼	69⅞
14⅞	46⅝-1/16	18⅝	58½	22⅜	70¼
15	47 1/16	18¾	58⅞	22½	70⅝
15⅛	47½	18⅞	59¼	22⅝	71 1/16
15¼	47⅞	19	59⅝-1/16	22¾	71⅜-1/16
15⅜	48¼	19⅛	60 1/16	22⅞	71¾-1/16
15½	48⅝-1/16	19¼	60⅜-1/16	23	72¼
15⅝	49 1/16	19⅜	60¾-1/16	23⅛	72⅝
15¾	49⅜-1/16	19½	61¼	23¼	73
15⅞	49¾-1/16	19⅝	61⅝	23⅜	73⅜

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
23½	73¾-1/16	27¼	85½-1/16	31	97⅜
23⅝	74⅛-1/16	27⅜	86	31⅛	97¾-1/16
23¾	74½-1/16	27½	86⅜	31¼	98⅛-1/16
23⅞	75	27⅝	86¾	31⅜	98½-1/16
24	75⅜	27¾	87⅛	31½	99
24⅛	75¾	27⅞	87½-1/16	31⅝	99⅜
24¼	76⅛	28	87⅞-1/16	31¾	99⅝-1/16
24⅜	76½-1/16	28⅛	88¼-1/16	31⅞	100 1/16
24½	76⅞-1/16	28¼	88¾	32	100½
24⅝	77¼-1/16	28⅜	89⅛	32⅛	100⅞
24¾	77¾	28½	89½	32¼	101⅛-1/16
24⅞	78⅛	28⅝	89⅞	32⅜	101⅝-1/16
25	78½	28¾	90¼-1/16	32½	102 1/16
25⅛	78⅞-1/16	28⅞	90⅝-1/16	32⅝	102½
25¼	79¼-1/16	29	91 1/16	32¾	102⅞
25⅜	79¾	29⅛	91⅜-1/16	32⅞	103¼-1/16
25½	80 1/16	29¼	91⅞	33	103⅝-1/16
25⅝	80½	29⅜	92¼	33⅛	104 1/16
25¾	80⅞	29½	92⅝	33¼	104½
25⅞	81¼	29⅝	93 1/16	33⅜	104⅞
26	81⅝-1/16	29¾	93⅜-1/16	33½	105⅛-1/16
26⅛	82 1/16	29⅞	93¾-1/16	33⅝	105½-1/16
26¼	82⅜-1/16	30	94¼	33¾	106
26⅜	82¾-1/16	30⅛	94⅝	33⅞	106⅜
26½	83¼	30¼	95	34	106¾-1/16
26⅝	83⅝	30⅜	95⅜	34⅛	107⅛-1/16
26¾	84	30½	95¾-1/16	34¼	107⅝
26⅞	84⅜-1/16	30⅝	96⅛-1/16	34⅜	108
27	84¾-1/16	30¾	96½-1/16	34½	108⅜
27⅛	85⅛-1/16	30⅞	97	34⅝	108¾-1/16

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
34¾	109⅛-1/16	38½	121	42¼	132⅝-1/16
34⅞	109⅝	38⅝	121⅜	42⅜	133 1/16
35	110	38¾	121¾	42½	133½
35⅛	110¼-1/16	38⅞	122⅛	42⅝	133⅞
35¼	110⅝-1/16	39	122½	42¾	134¼-1/16
35⅜	111 1/16	39⅛	122⅞	42⅞	134⅝-1/16
35½	111½	39¼	122¼-1/16	43	135 1/16
35⅝	111⅞	39⅜	123⅝-1/16	43⅛	135½
35¾	112¼-1/16	39½	124⅛	43¼	135⅞
35⅞	112⅝-1/16	39⅝	124½	43⅜	136¼-1/16
36	113 1/16	39¾	124⅞	43½	136⅝-1/16
36⅛	113½	39⅞	125¼-1/16	43⅝	137 1/16
36¼	113⅞	40	125⅝-1/16	43¾	137⅜-1/16
36⅜	114¼-1/16	40⅛	126 1/16	43⅞	137¾-1/16
36½	114⅝-1/16	40¼	126⅜-1/16	44	138⅛-1/16
36⅝	115 1/16	40⅜	126¾-1/16	44⅛	138½-1/16
36¾	115⅜-1/16	40½	127⅛-1/16	44¼	139
36⅞	115¾-1/16	40⅝	127⅝	44⅜	139⅜
37	116⅛-1/16	40¾	128	44½	139¾-1/16
37⅛	116½-1/16	40⅞	128⅜	44⅝	140⅛-1/16
37¼	117	41	128¾-1/16	44¾	140½-1/16
37⅜	117⅜	41⅛	129⅛-1/16	44⅞	141
37½	117¾-1/16	41¼	129⅝	45	141⅜
37⅝	118⅛-1/16	41⅜	130	45⅛	141¾-1/16
37¾	118½-1/16	41½	130⅜	45¼	142⅛-1/16
37⅞	119	41⅝	130¾-1/16	45⅜	142½-1/16
38	119⅜	41¾	131⅛-1/16	45½	142⅞-1/16
3 ⅛	119¾-1/16	41⅞	131½-1/16	45⅝	143¼-1/16
38¼	120⅛-1/16	42	131⅞	45¾	143⅝-1/16
38⅜	120½-1/16	42⅛	132¼-1/16	45⅞	144 1/16

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
46	144½	49¾	156¼-1/16	53½	168 1/16
46⅛	144⅞	49⅞	156⅝-1/16	53⅝	168½
46¼	145¼-1/16	50	157 1/16	53¾	168⅞
46⅜	145⅝-1/16	50⅛	157½	53⅞	169¼
46½	146 1/16	50¼	157⅞	54	169⅝
46⅝	146½	50⅜	158¼-1/16	54⅛	170
46¾	146⅞	50½	158⅝-1/16	54¼	170⅜
46⅞	147¼-1/16	50⅝	159 1/16	54⅜	170¾-1/16
47	147⅝-1/16	50¾	159⅜-1/16	54½	171⅛-1/16
47⅛	148 1/16	50⅞	159¾-1/16	54⅝	171½-1/16
47¼	148⅜-1/16	51	160⅛-1/16	54¾	172
47⅜	148¾-1/16	51⅛	160½-1/16	54⅞	172⅜
47½	149⅛-1/16	51¼	161	55	172¾-1/16
47⅝	149½-1/16	51⅜	161⅜	55⅛	173⅛-1/16
47¾	150	51½	161¾-1/16	55¼	173½-1/16
47⅞	150⅜	51⅝	162⅛-1/16	55⅜	174
48	150¾-1/16	51¾	162½-1/16	55½	174⅜
48⅛	151⅛-1/16	51⅞	163	55⅝	174¾
48¼	151½-1/16	52	163⅜	55¾	175⅛
48⅜	152	52⅛	163¾	55⅞	175½
48½	152⅜	52¼	164⅛	56	175⅞
48⅝	152¾-1/16	52⅜	164½	56⅛	176¼-1/16
48¾	153⅛-1/16	52½	164⅞	56¼	176⅝-1/16
48⅞	153½-1/16	52⅝	165¼-1/16	56⅜	177⅛
49	153⅞	52¾	165⅝-1/16	56½	177½
49⅛	154¼-1/16	52⅞	166 1/16	56⅝	177⅞
49¼	154⅝-1/16	53	166½	56¾	178¼
49⅜	155 1/16	53⅛	166⅞	56⅞	178⅝-1/16
49½	155½	53¼	167¼-1/16	57	179⅛
49⅝	155⅞	53⅜	167⅝-1/16	57⅛	179½

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
57¼	179⅞	61	191⅝	64¾	203⅜
57⅜	180¼	61⅛	192	64⅞	203¾-1/16
57½	180⅝	61¼	192⅜	65	204⅛-1/16
57⅝	181	61⅜	192¾-1/16	65⅛	204½-1/16
57¾	181⅜	61½	193⅛-1/16	65¼	205
57⅞	181¾-1/16	61⅝	193½-1/16	65⅜	205⅜
58	182⅛-1/16	61¾	194	65½	205¾-1/16
58⅛	182½-1/16	61⅞	194⅜	65⅝	206⅛-1/16
58¼	183	62	194¾-1/16	65¾	206½-1/16
58⅜	183⅜	62⅛	195⅛-1/16	65⅞	207
58½	183¾-1/16	62¼	195½-1/16	66	207⅜
58⅝	184⅛-1/16	62⅜	196	66⅛	207¾
58¾	184½-1/16	62½	196⅜	66¼	208⅛
58⅞	185	62⅝	196¾	66⅜	208½
59	185⅜	62¾	197⅛	66½	208⅞
59⅛	185¾	62⅞	197½	66⅝	209¼
59¼	186⅛	63	197⅞	66¾	209⅝-1/16
59⅜	186½	63⅛	198¼-1/16	66⅞	210⅛
59½	186⅞	63¼	198⅝-1/16	67	210½
59⅝	187¼-1/16	63⅜	199⅛	67⅛	210⅞
59¾	187⅝-1/16	63½	199½	67¼	211¼
59⅞	188⅛	63⅝	199⅞	67⅜	211⅝-1/16
60	188½	63¾	200¼-1/16	67½	212⅛
60⅛	188⅞	63⅞	200⅝-1/16	67⅝	212½
60¼	189¼-1/16	64	201⅛	67¾	212⅞
60⅜	189⅝-1/16	64⅛	201½	67⅞	213¼
60½	190 1/16	64¼	201¾-1/16	68	213⅝
60⅝	190½	64⅜	202⅛-1/16	68⅛	214
60¾	190⅞	64½	202½-1/16	68¼	214⅜
60⅞	191¼	64⅝	203	68⅜	214¾-1/16

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches	Inches.
68½	215⅛-1/16	72¼	227	76	238¾-1/16
68⅝	215½-1/16	72⅜	227⅜	76⅛	239⅛-1/16
68¾	216	72½	227¾-1/16	76¼	239½-1/16
68⅞	216⅜	72⅝	228⅛-1/16	76⅜	239⅞-1/16
69	216¾-1/16	72¾	228½-1/16	76½	240¼-1/16
69⅛	217⅛-1/16	72⅞	228⅞	76⅝	240⅝-1/16
69¼	217½-1/16	73	229¼-1/16	76¾	241⅛
69⅜	217⅞	73⅛	229⅝-1/16	76⅞	241½
69½	218¼-1/16	73¼	230⅛	77	241⅞
69⅝	218⅝-1/16	73⅜	230½	77⅛	242¼-1/16
69¾	219⅛	73½	230⅞	77¼	242⅝-1/16
69⅞	219½	73⅝	231¼-1/16	77⅜	243⅛
70	219⅞	73¾	231⅝-1/16	77½	243½
70⅛	220¼-1/16	73⅞	232⅛	77⅝	243⅞
70¼	220⅝-1/16	74	232½	77¾	244¼-1/16
70⅜	221⅛	74⅛	232⅞	77⅞	244⅝-1/16
70½	221½	74¼	233¼-1/16	78	245 1/16
70⅝	221⅞	74⅜	233⅝-1/16	78⅛	245⅜-1/16
70¾	222¼-1/16	74½	234 1/16	78¼	245¾-1/16
70⅞	222⅝-1/16	74⅝	234⅜-1/16	78⅜	246⅛-1/16
71	223 1/16	74¾	234¾-1/16	78½	246½-1/16
71⅛	223⅜-1/16	74⅞	235⅛-1/16	78⅝	247
71¼	223¾-1/16	75	235½-1/16	78¾	247⅜
71⅜	224⅛-1/16	75⅛	236	78⅞	247¾-1/16
71½	224½-1/16	75¼	236⅜	79	248⅛-1/16
71⅝	225	75⅜	236¾-1/16	79⅛	248½-1/16
71¾	225⅜	75½	237⅛-1/16	79¼	249
71⅞	225¾-1/16	75⅝	237½-1/16	79⅜	249⅜
72	226⅛-1/16	75¾	238	79½	249¾
72⅛	226½-1/16	75⅞	238⅜	79⅝	250⅛

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
79¾	250½	83½	262¼-1/16	87¼	274⅛
79⅞	250⅞	83⅝	262⅝-1/16	87⅜	274½
80	251¼-1/16	83¾	263⅛	87½	274⅞
80⅛	251⅝-1/16	83⅞	263½	87⅝	275¼-1/16
80¼	252⅛	84	263⅞	87¾	275⅝-1/16
80⅜	252½	84⅛	264¼-1/16	87⅞	276⅛
80½	252⅞	84¼	264⅝-1/16	88	276½
80⅝	253¼-1/16	84⅜	265⅛	88⅛	276⅞
80¾	253⅝-1/16	84½	265½	88¼	277⅛-1/16
80⅞	254⅛	84⅝	265⅞	88⅜	277½-1/16
81	254½	84¾	266¼-1/16	88½	278
81⅛	254⅞	84⅞	266⅝	88⅝	278⅜
81¼	255¼-1/16	85	267	88¾	278¾-1/16
81⅜	255⅝	85⅛	267⅜	88⅞	279⅛-1/16
81½	256	85¼	267¾-1/16	89	279½-1/16
81⅝	256⅜	85⅜	268⅛-1/16	89⅛	280
81¾	256¾-1/16	85½	268½-1/16	89¼	280⅜
81⅞	257⅛-1/16	85⅝	269	89⅜	280¾-1/16
82	257½-1/16	85¾	269⅜	89½	281⅛-1/16
82⅛	258	85⅞	269¾-1/16	89⅝	281½-1/16
82¼	258⅜	86	270⅛-1/16	89¾	282
82⅜	258¾-1/16	86⅛	270½-1/16	89⅞	282⅜
82½	259⅛-1/16	86¼	271	90	282¾
82⅝	259½-1/16	86⅜	271⅜	90⅛	283⅛
82¾	260	86½	271¾	90¼	283½
82⅞	260⅜	86⅝	272⅛	90⅜	283⅞
83	260¾	86¾	272½	90½	284¼-1/16
83⅛	261⅛	86⅞	272⅞	90⅝	284⅝-1/16
83¼	261½	87	273¼-1/16	90¾	285 1/16
83⅜	261⅞	87⅛	273⅝-1/16	90⅞	285½

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
91	285⅞	94¾	297⅝-1/16	98½	309⅜-1/16
91⅛	286¼-1/16	94⅞	298 1/16	98⅝	309¾-1/16
91¼	286⅝-1/16	95	298⅜-1/16	98¾	310⅛-1/16
91⅜	287 1/16	95⅛	298¾-1/16	98⅞	310½-1/16
91½	287⅜-1/16	95¼	299⅛-1/16	99	311
91⅝	287¾-1/16	95⅜	299½-1/16	99⅛	311⅜
91¾	288⅛-1/16	95½	300	99¼	311¾-1/16
91⅞	288½-1/16	95⅝	300⅜	99⅜	312⅛-1/16
92	289	95¾	300¾-1/16	99½	312½-1/16
92⅛	289⅜	95⅞	301⅛-1/16	99⅝	313
92¼	289¾-1/16	96	301½-1/16	99¾	313⅜
92⅜	290⅛-1/16	96⅛	302	99⅞	313¾-1/16
92½	290½-1/16	96¼	302⅜	100	314⅛-1/16
92⅝	291	96⅜	302¾-1/16	100⅛	314½-1/16
92¾	291⅜	96½	303⅛-1/16	100¼	314⅞-1/16
92⅞	291¾-1/16	96⅝	303½-1/16	100⅜	315¼-1/16
93	292⅛-1/16	96¾	303⅞-1/16	100½	315⅝-1/16
93⅛	292½-1/16	96⅞	304¼-1/16	100⅝	316⅛
93¼	293	97	304⅝-1/16	100¾	316½
93⅜	293⅜	97⅛	305⅛	100⅞	316⅞
93½	293¾	97¼	305½	101	317¼-1/16
93⅝	294⅛	97⅜	305⅞	101⅛	317⅝-1/16
93¾	294½	97½	306¼-1/16	101¼	318 1/16
93⅞	294⅞	97⅝	306⅝-1/16	101⅜	318⅜-1/16
94	295¼-1/16	97¾	307⅛	101½	318¾-1/16
94⅛	295⅝-1/16	97⅞	307½	101⅝	319¼
94¼	296⅛	98	307⅞	101¾	319⅝
94⅜	296½	98⅛	308¼-1/16	101⅞	320
94½	296⅞	98¼	308⅝-1/16	102	320⅜-1/16
94⅝	297¼-1/16	98⅜	309 1/16	102⅛	320¾-1/16

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
102¼	321⅛-1/16	106	333	109¾	344¾
102⅜.	321½-1/16	106⅛	333⅜	109⅞	345⅛
102½	322	106¼	333¾	110	345½
102⅝	322⅜	106⅜	334⅛	110⅛	345⅞-1/16
102¾	322¾	106½	334½	110¼	346¼-1/16
102⅞	323⅛-1/16	106⅝	334⅞-1/16	110⅜	346¾
103	323½-1/16	106¾	335¼-1/16	110½	347⅛
103⅛	323⅞-1/16	106⅞	335¾	110⅝	347½
103¼	324¼-1/16	107	336⅛	110¾	347⅞
103⅜	324⅝-1/16	107⅛	336½	110⅞	348¼-1/16
103½	325 1/16	107¼	336⅞	111	348⅝-1/16
103⅝	325½	107⅜	337¼-1/16	111⅛	349 1/16
103¾	325⅞-1/16	107½	337⅝-1/16	111¼	349½
103⅞	326¼-1/16	107⅝	338 1/16	111⅜	349⅞
104	326⅝-1/16	107¾	338½	111½	350¼
104⅛	327 1/16	107⅞	338⅞	111⅝	350⅝
104¼	327½	108	339¼	111¾	351
104⅜	327⅞	108⅛	339⅝	111⅞	351⅜-1/16
104½	328¼	108¼	340	112	351¾-1/16
104⅝	328⅝-1/16	108⅜	340⅜-1/16	112⅛	352¼
104¾	329 1/16	108½	340⅞	112¼	352⅝
104⅞	329⅜-1/16	108⅝	341¼	112⅜	353
105	329¾-1/16	108¾	341⅝	112½	353⅜
105⅛	330¼	108⅞	342	112⅝	353¾-1/16
105¼	330⅝	109	342⅜	112¾	354⅛
105⅜	331	109⅛	342¾-1/16	112⅞	354½-1/16
105½	331⅜-1/16	109¼	343⅛-1/16	113	355
105⅝	331¾-1/16	109⅜	343½-1/16	113⅛	355⅜
105¾	332⅛-1/16	109½	344	113¼	355¾
105⅞	332½-1/16	109⅝	344⅜	113⅜	356⅛

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
113½	356½-1/16	117¼	368¼-1/16	121	380⅛
113⅝	356⅞-1/16	117⅜	368¾	121⅛	380½
113¾	357¼-1/16	117½	369⅛	121¼	380⅞
113⅞	357¾	117⅝	369½	121⅜	381¼
114	358⅛	117¾	369⅞	121½	381⅝-1/16
114⅛	358½	117⅞	370¼	121⅝	382 1/16
114¼	358⅞	118	370⅝-1/16	121¾	382⅜-1/16
114⅜	359¼-1/16	118⅛	371 1/16	121⅞	382⅞
114½	359⅝-1/16	118¼	371⅜-1/16	122	383¼
114⅝	360 1/16	118⅜	371¾-1/16	122⅛	383⅝
114¾	360⅜-1/16	118½	372¼	122¼	384
114⅞	360⅞	118⅝	372⅝	122⅜	384⅜-1/16
115	361¼	118¾	373	122½	384¾-1/16
115⅛	361⅝	118⅞	373⅜-1/16	122⅝	385⅛-1/16
115¼	362	119	373¾-1/16	122¾	385⅝
115⅜	362⅜-1/16	119⅛	374¼	122⅞	386
115½	362¾-1/16	119¼	374⅝	123	386⅜
115⅝	363¼	119⅜	375	123⅛	386¾-1/16
115¾	363⅝	119½	375⅜	123¼	387⅛-1/16
115⅞	364	119⅝	375¾	123⅜	387½-1/16
116	364⅜	119¾	376⅛	123½	387⅞-1/16
116⅛	364¾	119⅞	376½-1/16	123⅝	388⅜
116¼	365⅛-1/16	120	377	123¾	388¾
116⅜	365½-1/16	120⅛	377⅜	123⅞	389⅛
116½	366	120¼	377¾	124	389½
116⅝	366⅜	120⅜	378⅛	124⅛	389⅞-1/16
116¾	366¾	120½	378½	124¼	390¼-1/16
116⅞	367⅛	120⅝	378⅞-1/16	124⅜	390⅝-1/16
117	367½	120¾	379¼-1/16	124½	391⅛
117⅛	367⅞-1/16	120⅞	379⅝-1/16	124⅝	391½

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
124 3/4	391 7/8	128 1/2	403 5/8-1/16	132 1/4	415 3/8-1/16
124 7/8	392 1/4	128 5/8	404 1/16	132 3/8	415 3/4-1/16
125	392 5/8-1/16	128 3/4	404 3/8-1/16	132 1/2	416 1/4
125 1/8	393 1/16	128 7/8	404 7/8	132 5/8	416 5/8
125 1/4	393 3/8-1/16	129	405 1/4	132 3/4	417
125 3/8	393 3/4-1/16	129 1/8	405 5/8	132 7/8	417 3/8
125 1/2	394 1/4	129 1/4	406	133	417 3/4-1/16
125 5/8	394 5/8	129 3/8	406 3/8-1/16	133 1/8	418 1/8-1/16
125 3/4	395	129 1/2	406 3/4-1/16	133 1/4	418 1/2-1/16
125 7/8	395 3/8-1/16	129 5/8	407 1/8-1/16	133 3/8	419
126	395 3/4-1/16	129 3/4	407 1/2-1/16	133 1/2	419 3/8
126 1/8	396 1/4	129 7/8	408	133 5/8	419 3/4
126 1/4	396 5/8	130	408 3/8	133 3/4	420 1/8
126 3/8	397	130 1/8	408 3/4	133 7/8	420 1/2-1/16
126 1/2	397 3/8	130 1/4	409 1/8-1/16	134	420 7/8-1/16
126 5/8	397 3/4	130 3/8	409 1/2-1/16	134 1/8	421 1/4-1/16
126 3/4	398 1/8-1/16	130 1/2	409 7/8	134 1/4	421 3/4
126 7/8	398 1/2-1/16	130 5/8	410 1/4-1/16	134 3/8	422 1/8
127	399	130 3/4	410 3/4	134 1/2	422 1/2
127 1/8	399 3/8	130 7/8	411 1/8	134 5/8	422 7/8
127 1/4	399 3/4	131	411 1/2	134 3/4	423 1/4-1/16
127 3/8	400 1/8	131 1/8	411 7/8-1/16	134 7/8	423 5/8-1/16
127 1/2	400 1/2	131 1/4	412 1/4-1/16	135	424 1/16
127 5/8	400 7/8	131 3/8	412 5/8-1/16	135 1/8	424 1/2
127 3/4	401 1/4-1/16	131 1/2	413 1/16	135 1/4	424 7/8
127 7/8	401 5/8-1/16	131 5/8	413 1/2	135 3/8	425 1/4
128	402 1/16	131 3/4	413 7/8	135 1/2	425 5/8
128 1/8	402 1/2	131 7/8	414 1/4	135 5/8	426 1/16
128 1/4	402 7/8	132	414 5/8-1/16	135 3/4	426 3/8-1/16
128 3/8	403 1/4	132 1/8	415 1/16	135 7/8	426 3/4-1/16

DIAMETERS AND CIRCUMFERENCES OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
136	427¼	138¾	435⅞	141½	444½
136⅛	427⅝	138⅞	436¼	141⅝	444⅞
136¼	428	139	436⅝	141¾	445¼-1/16
136⅜	428⅜-1/16	139⅛	437	141⅞	445⅝-1/16
136½	428¾-1/16	139¼	437⅜-1/16	142	446 1/16
136⅝	429⅛-1/16	139⅜	437¾-1/16	142⅛	446⅜-1/16
136¾	429½-1/16	139½	438¼	142¼	446⅞
136⅞	430	139⅝	438⅝	142⅜	447¼
137	430⅜	139¾	439	142½	447⅝
137⅛	430¾	139⅞	439⅜	142⅝	448 1/16
137¼	431⅛	140	439¾-1/16	142¾	448⅜-1/16
137⅜	431½-1/16	140⅛	440⅛-1/16	142⅞	448¾-1/16
137½	431⅞-1/16	140¼	440½-1/16	143	449¼
137⅝	432¼-1/16	140⅜	441	143⅛	449⅝
137¾	432⅝-1/16	140½	441⅜	143¼	450
137⅞	433⅛	140⅝	441¾	143⅜	450⅜
138	433½	140¾	442⅛	143½	450¾
138⅛	433⅞	140⅞	442½-1/16	143⅝	451⅛-1/16
138¼	434¼-1/16	141	442⅞-1/16	143¾	451½-1/16
138⅜	434⅝-1/16	141⅛	443¼-1/16	143⅞	451⅞-1/16
138½	435 1/16	141¼	443¾	144	452⅜-1/16
138⅝	435½	141⅜	444⅛		

CHAPTER III.

PRACTICAL GEOMETRY, AS REQUIRED BY BOILERMAKERS.

To bisect a given right line.—That is, to divide it, or square it across in two equal parts. Let A B, Fig. 25, be the given right line. Then, with any radius greater than A E,—that is greater than half the length of the line,—and on A and B, as centres, describe two arcs cutting each other at C and D; draw the line C E D through the intersections. Then C E D will be at right angles to A E, and the line A B is divided into two equal parts at E.

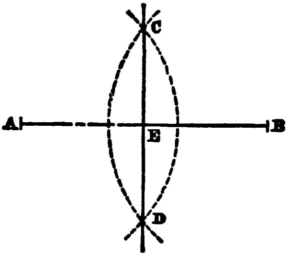


Fig. 25.

To draw a perpendicular to a straight line from one of its extremities.—Let A B, Fig. 26, be the given line, and B the extremity from which the perpendicular is to be drawn. Take any point, C, and with the radius C B describe an arc of a circle, A B D; draw a line from A, through C,

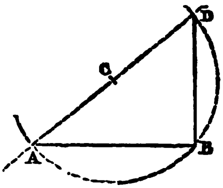


Fig. 26.

cutting the arc at D; then, a line drawn through the intersection at D from B will be perpendicular to A B.

To draw a perpendicular to a right line from a point without the line; that is, when the point is not on the line. Let A B, Fig. 27, be the given line, and C the point through which the perpendicular is to be drawn. Then, on C as a centre, with any radius greater than the distance to the line A B, describe an arc cutting A B at E and F; and on E and F as centres, with any radius greater than E D, describe two arcs cutting each other at E; a line drawn through E and C will be perpendicular to A B.

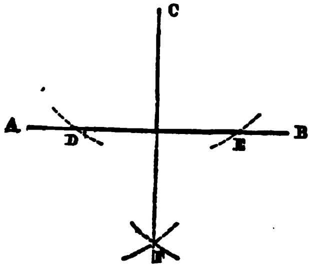


Fig. 27.

To draw a line parallel to a given straight line.—FIRST, to draw the parallel at a given distance. Let A B, Fig. 28, be the given line. Open the compasses to the distance required, and from any two points, C and D, describe arcs E and F. Draw the line G H, touching the arcs. It is the required parallel.

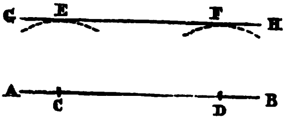


Fig. 28.

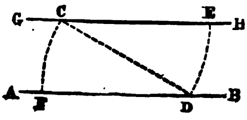


Fig. 29

SECOND, to draw a parallel through a given point. Let C, Fig. 29, be the point. From C draw any line C D to A B. On C D, as centres, describe arcs D E and E F. Cut off D E equal to C F, and through the points C and E, draw the parallel G H.

To draw a rectangle from the centre lines.—Draw the line A B, Fig. 30, equal to one of the centre lines, bisect it at C, draw the other centre line, D E, through C, at right angles to A B; then with C D as a radius, and on B and A as centres, describe arcs at H, J, F, and G; again with C A as radius, on E and D as centres, describe arcs cutting the arcs at H, J, F, and G. Join the intersections by straight lines, these will be at right angles and will form a rectangle.

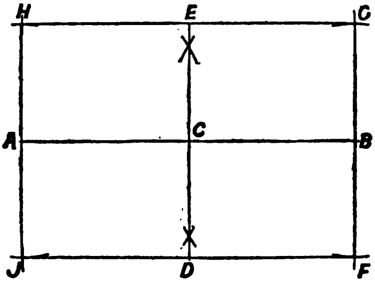


Fig. 30.

To draw a square on a given line.—Let A B, Fig. 31, be the given line. Erect a perpendicular at B, and on B as a centre, with B A as a radius, describe an arc at D,

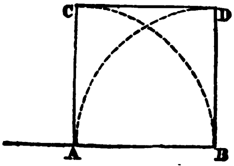


Fig. 31.

and on D as a centre describe another arc at C. On A as a centre, with the same radius describe an arc cutting the other arc at C. Join the intersections by straight lines, and the square is formed. If truly square, it should measure the same length in the two diagonal directions; that is, the distance A D should be equal to the distance B C.

To bisect an angle.—That is, to divide it in two equal angles. On the point of the angle, A, Fig. 32, as a centre, with any radius, describe an arc cutting the sides of the angle at D and E, and on D and E as centres, describe two arcs cutting each other at F. The line drawn through A and F will bisect the angle.

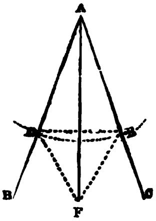


Fig 32.

Upon a given right line to construct an equilateral triangle.—Let A B, Fig. 33, be the given right line; then on A and B, with A B as radius, describe two arcs cutting each other at C, join A C and B C, and the triangle A B C, thus formed, is an equilateral triangle.

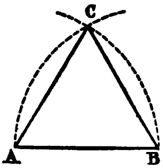


Fig. 33.

In a given circle to inscribe a square.—Draw any two diameters at right angles to each other, and join the extremities, as in Fig. 34.

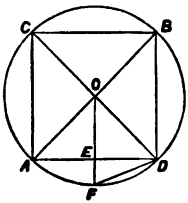


Fig. 34.

To inscribe an octagon.—First inscribe the square, then bisect the quarter circles and join the extremities. Or, bisect the angle

A O D, Fig. 34, by the line O F. Then D F is the length of the side of the octagon.

To draw a circle through three given points, no matter how they are placed.—This is a very useful problem, as it enables any one to determine the diameter of the circle of which an arc is a part. Place the three points, 1, 2, 3, anywhere. With any radius greater than half the distance between two of the points, 1 and 2, and on these points as centres, describe two arcs cutting each other at A and B. Similarly, describe intersecting arcs on the points 2 and 3 as centres. Draw straight lines through the intersections respectively, meeting at O. Then O is the centre from which the arc is to be described, with the radius O 1, which will pass through all the three points.

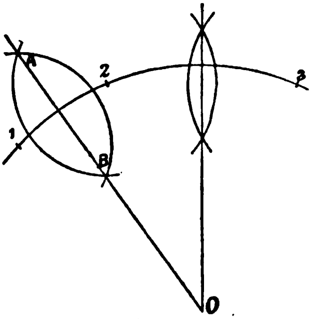


Fig. 35.

To draw a straight line equal in length to a given arc of a circle.—Divide the chord A B into four equal parts; set off one of these parts from B to C, and join C D. The line C D is equal to the length of half the given arc nearly.

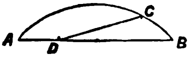


Fig. 36.

To describe a rectangle when the length of the diagonal and that of one of the ends is given.—Draw the diagonal A B. Bisect it at the centre O, and with

O A as radius, describe a circle. Set off the length of the end from A, cutting the circle at D, and from B cutting the circle at C; and join A C, C B, B D, and D A, to form the rectangle required.

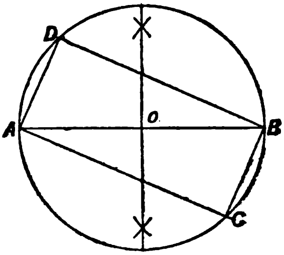


Fig. 37.

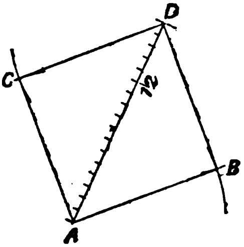


Fig 38.

To construct a square whose diagonal only is given.—Divide the diagonal into seventeen equal parts. Twelve of these parts are the measure of the side of the square. From A take up twelve parts in the compasses, and draw arcs of a circle at B and at C; and on D as a centre, with the same radius, draw arcs, cutting those at C and D, and join the intersections to form the square A B D C.

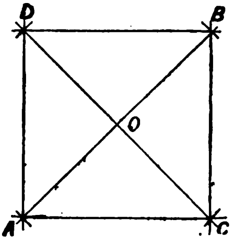


Fig. 39.

Another method.—Bisect the diagonal at O, by the perpendicular line C D; and on the centre O and with the radius O B, describe arcs at C and D. Join the intersections to form the square A C B D.

To draw a square equal in area to a given circle.—Divide the diameter A B into fourteen equal parts: set off eleven of these from A to O, and from O draw the perpendicular O C, cutting the circle at C; and draw A C. Then A C is the side of a square of which the area is equal to that of the circle. To complete the square, from C draw a line through the centre of the circle, cutting the circumference at E; and from A draw the straight line A E F, through the point E. This line is at right angles to A C. With the radius A C, and on A as a centre, describe an arc at F; and on F, with the same radius, draw an arc at G. From C, again, draw an arc cutting the former at G with the same radius. Join the intersections, and the square is completed.

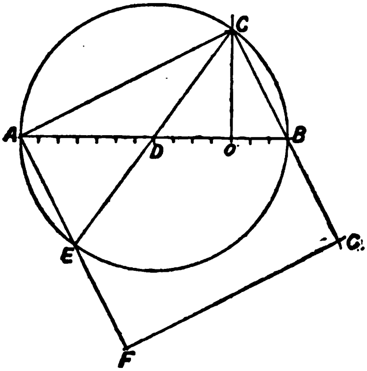


Fig. 40.

Or, multiply the diameter of the circle by ·886226: the product is the side of a square of equal area.

To draw a square equal in area to a given triangle.—Let B P A be the given triangle. Draw the perpendicular P C from the summit P, and bisect it. Produce the side of the triangle B A, and set off A E equal to the half of P C. Divide E B into two equal parts at D; and on D as centre, with D B as radius, describe the semicircle E B. Draw the perpendicular A F, cutting the circle at F; then A F is the side of a square equal in area to that of the given triangle.

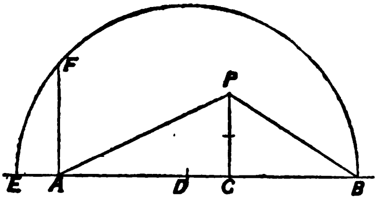


Fig. 41.

Another method.—A right-angled triangle being given, to construct a square of the same area. Divide the diagonal into thirty-four equal parts; set off ten of these parts from A, and ten from B,

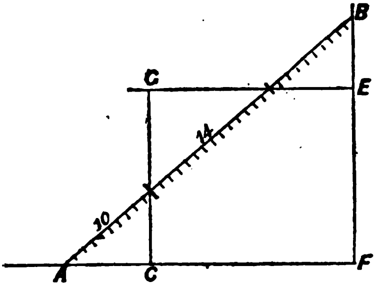


Fig. 42.

leaving fourteen in the middle. Draw C G and G E through the ten divisions, parallel to F E and C F respectively. The square C F E G has an area equal to that of the triangle A B F.

To produce a circle equal in area to a given square. — Given the square A B C D; draw the diagonals, and divide half a diagonal, O C, into fifteen equal parts. On O as centre, and with a radius of twelve of these parts, describe a circle. This circle is of the same area as the square.

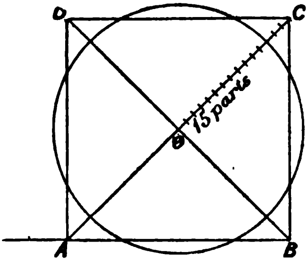


Fig. 43.

Or, multiply the side of the square by 1·12837. The product is the diameter of a circle equal in area to the square of which the side is given.

The square is divided into four triangles, each of which is one-fourth of the square in area. The quarter circles, whose figures differ of course materially from those of the triangles, have each the same area as one of the triangles.

To find the side of a square which shall contain the area of a given square any EVEN *number of times.* —Draw the given square A E. The diagonal F G is the side of a square of double the area of the given square. Set-off E H, equal to the diagonal F G; then the square E B has four times the area of the given square. Set off, again, E I, equal to the diagonal H J of the square E B, and draw the square E C on that base; the square E C has twice the area of E B, or four times that of the square E A. Set off E L equal to the diagonal I K; the square E D, erected on that base, has twice the area of E C. And so on.

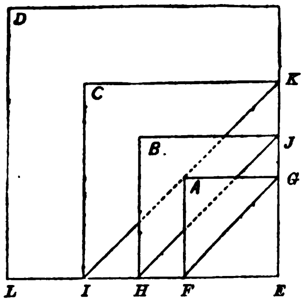


Fig. 44.

To draw an ellipse approximately, of a given length without regard to breadth. — Divide the given length into three equal parts at O and V; and on O and V as centres, with A O as radius, describe two circles cutting each other at I and K; on I and K as centres, with the diameter of the circle A O V as radius, describe the arcs D E, F G, to complete the form of an ellipse.

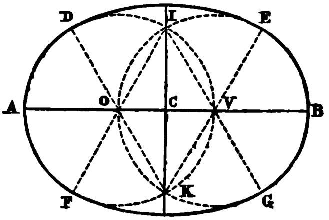


Fig. 45.

If the radius of the ends is too large and flat, divide the given length into four equal parts, Fig. 45A, and describe three circles as shown; and on H and F as centres,

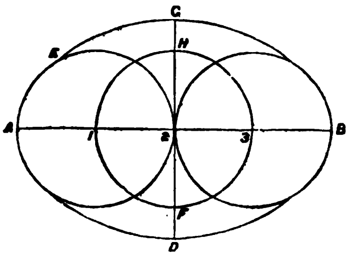


Fig. 45A.

describe the lateral arcs to touch the first and third circles, and so complete the figure.

To draw an ellipse when the length and breadth are given.—Draw the diametrical lines at right angles to each other, intersecting at O. Set out the length and breadth of the figure on these lines, equally from the centre O. Set off the length O D with the compasses on the longer diameter from B to E, and on O as a centre, with the radius O E,

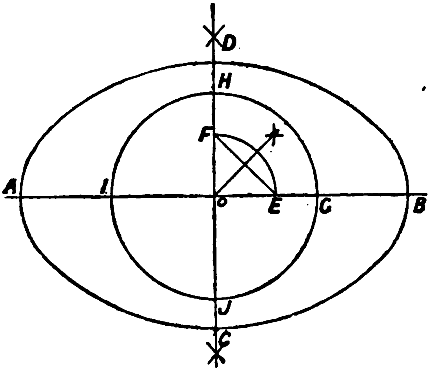


Fig. 46.

describe the quadrant E F. Draw the line or chord E F, and set off the half of it from E to G. On O as a centre, with O G as radius, describe the circle G H J I; then I and G are the centres for the segmental arcs at A and B, and H and J are the centres for the lateral arcs at C and D.

To draw an ellipse when the diameters are not at right angles to each other.—Let A B and C D be the two diameters. Draw the bounding lines

parallel to the diameters; divide A B into any number of equal parts; divide also E F and H G at each end into the same number of equal parts, then from C draw lines through the points 1, 2, 3, 4, &c.

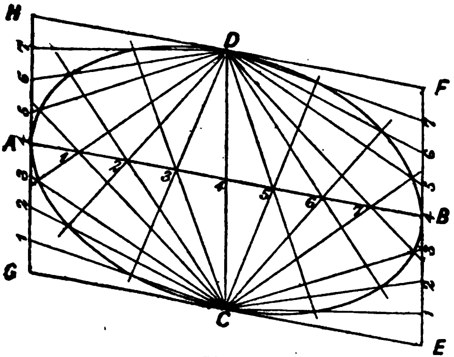


Fig. 47.

in the line A B; and do the same from D. From D again draw lines through the points 5, 6, 7, between B and F, and between H and A. From C draw lines through the points 1, 2, 3, between E and B, and A and G. The intersections of these radial lines give points in the curve of the ellipse, as shown in the diagram.

NOTE.—The distinction between an oval and an ellipse is this:—The oval is egg-shaped, that is, one end is smaller than the other; whilst in the ellipse both ends are alike.

CHAPTER IV.

TANKS AND CISTERNS.

Tanks and cisterns are of various forms, but their capacity can be readily calculated according to the rules already given for finding the contents of regular bodies. In the following examples the rules are adapted for giving the capacity in gallons.

Plain Rectangular Cistern.—Multiply the length by the breadth, and by the depth, all in inches; and multiply the last product by ·003606. The final product is the capacity in imperial gallons. For example, if the cistern be 12 inches wide, 36 inches long, and 12 inches deep, then :—

12 × 12 = 144 × 36 = 5184 × ·003606 = 18·693504 gals.

```
       12
       12
     ----
      144
       36
     ----
      864
     432
     ----
     5184
  ·003606
  -------
    31104
   31104
  15552
 --------
18·693504 gallons.
```

If the dimensions be given in feet, adopt the numerical multiplier, 6·232, to find the capacity in gallons.

For a cistern of a given length and width, to find the depth necessary for a given capacity. Multiply the length A B, by the width A C, both in feet; and then multiply the product by 6·232. Divide the given number of gallons by the last product. The quotient is the depth, B D, in feet. For example, a tank is 5 feet long by 4 feet wide, and it is required to be of sufficient capacity to hold 400 gallons. What is the depth required?

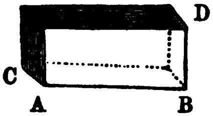


Fig. 48.

5 × 4 = 20 square feet, the superficial area.
20 × 6·232 = 124·640.

$\frac{400}{124\cdot640} = 3\cdot241231$ feet, the depth required.
12
Inches 2·894772
8
8ths 7·158176
4
32nds 0·632704

Depth 3 feet 2⅞ inches.

To find the number of gallons that can be held in a cylindrical vessel, having flat ends. Multiply the square of the diameter in inches by the length in inches, and the product by ·002832. The final product is the capacity in imperial gallons.

Or, multiply the square of the diameter in feet by the length in feet, and the product by 4·895. The product is the capacity in imperial gallons.

To find the diameter necessary for a cylindrical tank of a given length, to hold a given number of gallons. Multiply the number of gallons by 353·03, and divide the product by the given length in inches. The square root of the product is the diameter. Thus, for a cistern 18 inches long, to hold 8 gallons, what is the diameter required? $353{\cdot}03 \times 8 = \frac{2824{\cdot}24}{18} = 156{\cdot}90$, the square root of which is 12·5, the required diameter in inches.

Segmental Tank.—Suppose a tank, the end of which is a segment of a circle; it is required to find the capacity in gallons. Multiply the area of the end in square inches by the length in inches, and by ·003606. The product is the capacity in gallons.

Fig. 49.

Prismatic or Triangular Tank.—To find the number of gallons it will hold, multiply the area of the base by the length, both in inches, and divide the product by 277·274; or multiply the product by ·003606. The quotient is the capacity in imperial gallons.

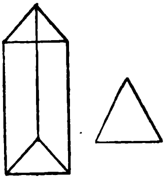


Fig. 50.

When the base is an equilateral triangle, the area of the base may be found by the rule, page 11.

Example.—What is the content in gallons of a triangular tank, of which the side of the base is 48 inches and the depth is 60 inches? 48 × 48 = 2304; and 2304 ÷ 4 = 576; and 576 × 1·732 = 997·632 = the area of the base in square inches. The area 997·632 multiplied by the length, 60 = 59857·920, which, divided by 277·274, or multiplied by ·003606 = 215·8 gallons, the capacity.

Sphere or Globe.—To find the capacity in gallons, multiply the cube of the diameter in inches by ·001888. The product is the capacity in imperial gallons. Let the diameter of a globe be 34 inches, what is the capacity in imperial gallons? 34 × 34 × 34 = 39294; and 39294 × ·001888 = 74·187072 imperial gallons.

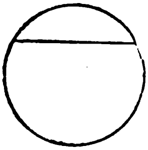


Fig. 51.

A Segment of a Sphere.—Multiply the square of half the diameter by 3, and to the product add the square of the height of the segment—the diameter and the height being expressed in inches; multiply the sum by the height and by ·001888. The final product is the capacity in gallons.

For instance, the crown of a donkey boiler. The diameter of the segment is 16, and the height is 3; then the half of the diameter is 8; and 8^2, or 8 × 8 = 64; then 64 × 3 = 192. The square of the height is 3 × 3 = 9; and 9 + 192 = 201;

201 × 3 = 603, and 603 × ·00188 = 1·128464 gallons, the capacity: say, 1·128 or about $1\frac{1}{8}$ gallons.

To find the capacity of a frustum of a cone.—Multiply the greater diameter in inches by the less, and the product by 3. Add the square of the difference between the two diameters, and multiply the sum by $\frac{1}{3}$ of their depth; then divide the product by 353·03 for imperial gallons.

Take the case of an ordinary pail or bucket, of which the form is a frustum of a cone. Required the number of gallons of water that a bucket will hold, the diameter of the greater end being 20 inches, that of the less end 16 inches, and the depth 20 inches. Then 20 × 16 = 320; and 320 × 3 = 960. Again, 20 − 16 = 4; and 4 × 4 = 16, the square of the difference of the diameters; then 16 + 960 = 976; and 976 × $\frac{1}{3}$ of the depth, or by 20 ÷ 3 = 6·625, is 976 × 6·625 = 6466; and 6466 ÷ 353·03 = 18·31 gallons, the capacity.

Another way to find the capacity in gallons of a frustum of a cone.—Add the two diameters together, and divide by 2 for the mean diameter. Square this new diameter, multiply it by the length, and that product by ·002832 for the content in gallons, if the dimensions are given in inches, or by 4·895 if given in feet.

To find the capacity of the frustum of a square pyramid.—The rule is the same as the first above, for a conical frustum, except that the divisor for gallons of capacity is 277·274.

Saddle Tank of a Locomotive Engine.—This is a case of the rule, page 7, for the area of a segment of a ring. Multiply the area of the end by the length, for the cubic content. If the dimensions are given in inches, multiply that product by ·003606 for gallons of capacity; and if the dimensions are given in feet, multiply by 6·232 for the capacity. Adopting the dimensions of the arcs given in the example, page 7, namely, the arc A X D, 90 inches long, the arc B C, 40 inches long, and the distance apart of the arcs, or breadth of the ring, A B or C D, 18 inches. Taking a length of 12 feet or 144 inches, then the area of the end is equal to $(90 + 40) \div 2 = 65$; and $65 \times 18 = 1170$ square inches; and $1170 \times 144 = 168480$ cubic inches $\times$ ·003606 = 607·538 gallons.

CHAPTER V.

RECTANGULAR AND CIRCULAR WORK.

It has been shown how the boiler-maker can square off a plate.

To find the length of plate required to form a cylinder of a given diameter.—The length of plate is equal to the circumference measured on the centre line of the bent plate; and the diameter from which to reckon the circumference is the mean diameter, measured from centre to centre of the plate. Suppose, for instance, a flue or a cylinder of any other kind is to be constructed to a diameter of 24 inches inside, of plate $\frac{1}{4}$ thick. Then the mean diameter, required, from which the circumference is to be calculated for the necessary length of the plate, is equal to 24 plus half the thickness of plate at both sides, as in Fig. 52, or to $24 + \frac{1}{8} + \frac{1}{8} = 24\frac{1}{4}$. That is, it is equal to the inside diameter plus the thickness of plate. Then the product of $24\frac{1}{4}$ multiplied by 3·1416, equals the circumference. Thus, the decimal expression of $24\frac{1}{4}$ is 24·25 or 24 point $\frac{25}{100}$, which multiplied by $3{\cdot}1416 = 76{\cdot}1838$, that is 76 inches and ·1838 decimal parts of an inch.

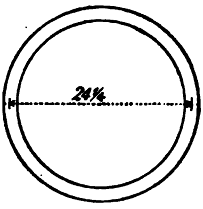


Fig. 52.

To find how many 8th parts of an inch are contained in these decimal parts, multiply them by 8, and point off from the right-hand side an equal number of decimal places. Again, multiply the decimals last pointed off by 4, and again point off an equal number of decimals. The figure on the left-hand side of the decimal point is the number of 32nd parts of an inch remaining after the 8th parts have been extracted. If there be a decimal remainder, it may be multiplied by 2, to show the number of 64th parts in it. Thus, to multiply, in the first place, 24·25 inches × 3·1416 :—

```
                      3·1416
                       24·25
                     -------
                      157080
                      62832
                     125664
                     62832
                   ---------
76 inches          76·183800
                           8
                   ---------
One-8th             1·470400
                           4
                   ---------
One-32nd            1·881600
                           2
                   ---------
One-64th            1·763200
                   =========
```

Circumference is $76\frac{1}{8}\,\frac{1}{32}\,\frac{1}{64}$ and something over: or $76\frac{1}{8}\,\frac{3}{64}$.

Though there is only one whole 64th part in the last line of the calculation, yet there is more than 7-10ths of another 64th over in the decimal remainder; and it would be better to take the measure as two 64ths or 1-32nd; and adding this to the first 32nd part, there are two 32nd parts, or ⅛ part, to add to the one 8th part already found, making together two 8ths or ¼. Hence the most nearly exact measure for the circumference is 76¼ inches.

Another method.—By the approximate rule before given, for the circumference of a circle, multiply the diameter, 24¼ inches, by 22, and divide by 7. Then find the value of the decimal in fractions of an inch as before. Thus:—

```
               24·25
                  22
               ─────
                4850
               4850
              ──────
           7)533·50
              ──────
76 inches     76·214
                   8
              ──────
One-8th        1·712
                   4
              ──────
Two-32nds      2·848
                   2
              ──────
One-64th       1·696
               ═════
```

Circumference is $76\frac{1}{8}\ \frac{2}{32}\ \frac{1}{64}$, and something over.

Here it appears that the length as found is one 32nd greater than was given by the first calculation.

If two, three, or any greater number of plates are to be used in order to form the circle of plates for a cylindrical boiler, the circumference as given by the foregoing rules is to be divided correspondingly, to give the net length of each plate taken to the centre lines of the rivet-holes. For lap-joints, lap, of course, is to be added to the net length of each plate, at each end, in order to form the joint.

When the cylinder is to be welded at the joint, instead of being riveted, corresponding allowance is to be made. When a weld is made with a filling-piece, as in Fig. 53, the edges of the plate or plates are usually kept apart by as much as the thickness of the plate, and are of course cut shorter by the same amount, than the calculated circumference. A filling-piece is inserted to form the weld.

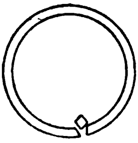


Fig. 53.
Welded Seam.

When the cylinder is to be lap-welded, an extra length of plate, equal to twice the thickness of the plate, is allowed for lap, as in Fig. 54.

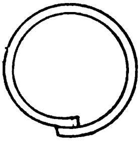


Fig. 54.
Lap Seam.

Square-end Tank.—It is wanted to make a square-end tank as in Fig. 55, and to put in all the holes before the plate is bent. Care must be taken to mark it right, because if it is to be 12 inches outside it will readily be seen that in bending each corner you will add one thickness of the plate to the width. Therefore, in marking it out, leave each side one thickness shorter, and put in the holes at equal distances on each side of the corner line. When it is bent, and it fits the gauge, 12 inches outside measurement, the holes will be equally on each side of the corner.

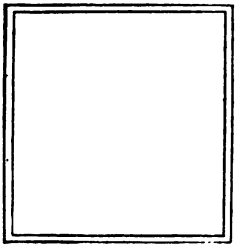
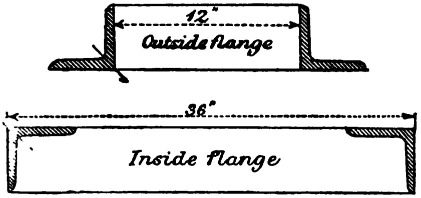


Fig. 55.—Square-end Tank.

Angle-iron rings and framing.—The length of angle-iron required for the formation of a ring of a given diameter, varies according to the thickness of the iron at the root, and also with the heat of the bar when it is bent. The hotter it is, it bends the more easily, and it does not take up quite so much stuff. Therefore, in bending a number of rings, care should be taken to equalise the heat, for if one is bent very hot, and another at half-heat, there will be some difference in the diameters when cold.

To find the length of angle-iron necessary for forming a ring of a given diameter.—When the flat flange is outside the ring or cylindrical flange, Fig. 56: to the interior diameter add twice the extreme or slant thickness of the iron at the root, as indicated in the figures, and multiply the sum by 3·1416. The product is the length required. For example, let the interior diameter for an outside-flange ring, Fig. 56, be 12 inches, and the thickness at the root ¾ inch. Then ¾ × 2 = 1½, and 12 + 1½ = 13½; and 13½ × 3·1416 = 42·4116 inches, the length of the iron necessary.



Figs. 56 and 57.—Angle-iron Rings.

When the flat flange is inside the ring, Fig. 57:

from the exterior diameter subtract twice the extreme thickness of the iron at the root, and multiply the difference by 3·1416. The product is the length required. For example, the ring is to be 3 feet in diameter from heel to heel, and $\frac{3}{4}$ inch thick at the root; subtract twice $\frac{3}{4}$ inch, or $1\frac{1}{2}$ inches, from 36 inches, leaving $34\frac{1}{2}$ inches. Then $34\frac{1}{2} \times 3{\cdot}1416 = 108{\cdot}3852$ inches = 9 feet $\frac{3}{8}$ inch, the length required.

NOTE.—Instead of multiplying by 3·1416, the adjusted diameter may be multiplied by 3, and $\frac{9}{16}$ inch added to the product, for each foot in the product. The sum is the required length.

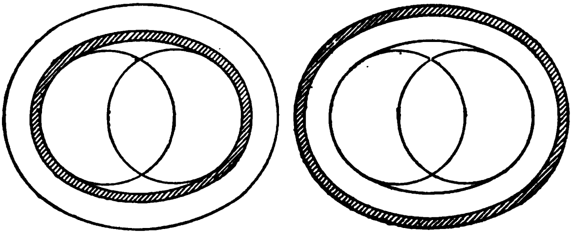


Fig 58.—Outside Flange. Fig. 59.—Inside Flange.
Elliptical Angle-iron Rings.

Another common method is to multiply the adjusted diameter by 3, and add 1-7th of the diameter to the product.

For elliptical rings of angle-iron add together the two diameters, and divide by 2, to obtain the mean diameter. Then, proceed according to the rules for circular rings; adding to the mean diameter twice the thickness of the angle-iron at the root, for outside flanges; and subtracting the same for inside flanges. Figs. 58 and 59.

For rings of T iron, to find the length of iron required, the rule is the same as for ordinary angle iron, simply adding or subtracting the thickness of the diagonal root of the bar, according as the ring is to be an outside or an inside flange.

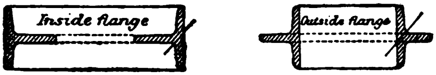


Fig. 60. Fig. 61.

T Iron Rings.

To make an angle-iron frame, as in the figure. From the finished length of the frame, A B, subtract two thicknesses of the flange, for this reason, that in turning the ends, A C and B D, the thickness of the iron is gained. If this is not attended to, the corner will need to be staved up after being bent.

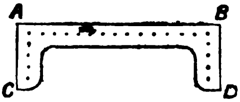


Fig. 62.—Angle-iron Frame.

The table of circumferences of circles, given in Chapter II., can be used for angle-iron rings, by simply adding to the given diameter twice the thickness of the iron at the root for an outside flange; and by subtracting twice the thickness at the root for an inside flange, to give the adjusted diameter. Opposite this diameter, in the table, the proper net length is given in the columns of circumferences, exclusive of lap. It forms a butt-joint of the two ends.

CHAPTER VI.

TEMPLATING.

In the discussion of the following problems of templating, or setting out plates for the construction of boiler work in various forms, the dimensions, written and drawn, are taken at the centre lines of rivet-holes, or at jump-joints, when welts or butt-plates are employed for making the joints. The lap of plates is not taken into consideration in the drafting of the work, unless for the purpose of ascertaining that there is stuff enough in the plate to be cut. But when the rivet-holes have been marked off, an addition for lap is made to the outline.

A table of the proportions for lap joints of plates of various thicknesses is given, further on, for reference.

To develop or lay out the junction of two cylinders of equal diameters when the extremities meet; or to draw or develop an elbow or knee; as, for instance, the knee of the chimney of a donkey boiler. Lay down on a board the required angle of the pipe as in the Fig. 63. It is to be made to join or metre together at A B. Draw the line

C D at any distance convenient for the compasses, from A, at right angles to the centre line, and at any convenient distances draw two semicircles E F and G H. Divide each of these semicircles into the same even number of equal parts, 1, 2, 3, &c. Place a straight-edge to the corresponding points of division in the two semicircles, as 1 1, 2 2, and so on. In each position it will be parallel to the axis of the cylinder. For each position, successively, draw the ordinates I, J, K, &c., from the base C D, to the junction line A B. Next, lay down the plate from which it is to be cut, and

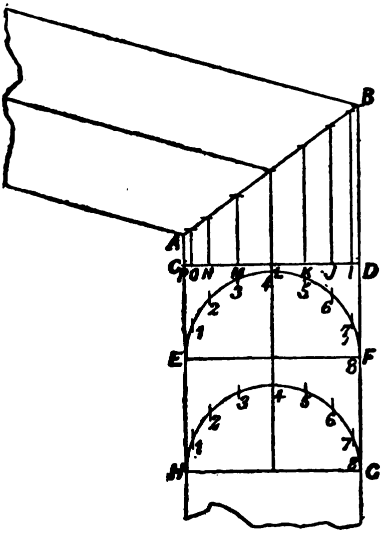


Fig. 63.—Cylinder Knee.

square it to the length of the circumference required to make up to the given diameter, as in Fig. 64. Then draw a line A B, Fig. 64, in a line with C D, Fig. 63, and draw the parallel D C, Fig. 64, at a distance equal to D B, Fig. 63, above A B, and divide A B, Fig. 64, into as many parts on each side of the centre o′, as there are in the whole semicircle, Fig. 63; and draw perpendiculars through the points of division, I, J, K, &c. This having been done, take the compasses and measure from the line C D, Fig. 63, the length of the perpendicular I, and set off the distance thus found from the base A B on the line I, on each side of the centre o′, Fig. 64. Again, measure the length of the line J, Fig. 63, and from the

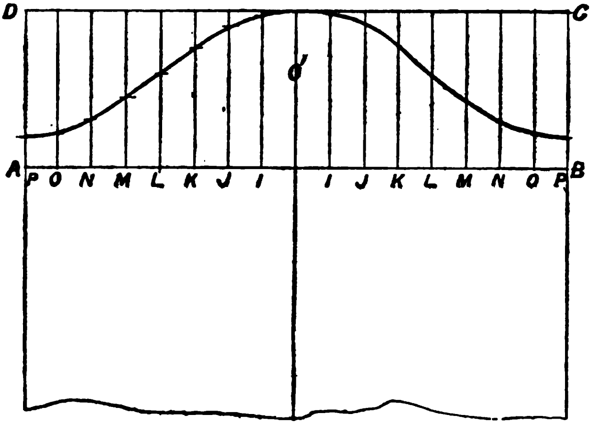


Fig. 64.—Cylinder Knee. Development when the Seam is on the Shorter Side.

base mark its distance on the lines J, Fig. 64. Measure all the lines in the same way, and draw the curve on Fig. 64, through the intersections, by means of a thin stick, or by hand if necessary. The greater the number of parts into which the semicircles are divided, the greater also and closer are the number of points on Fig. 64, and the more accurately may the curve be traced. When it is drawn, cast the eye along the curve, in order to detect any flat or irregular places that may be in it, and correct them. Always aim at having an odd number for the centre line, as it is more convenient than an even number.

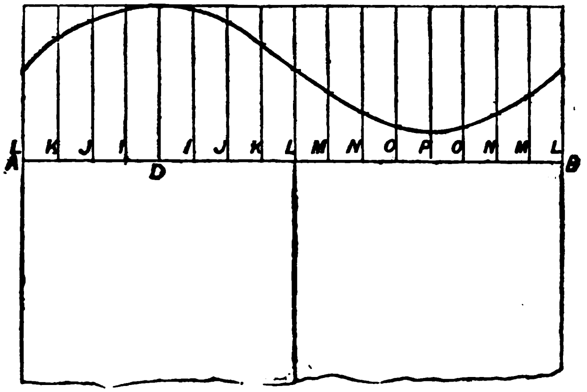


Fig. 65.—Cylinder Knee. Development when the Seam is at Line L.

In Fig. 65 is shown the shape to which the plate is required to be cut if the seam of rivets is to be in the side, as at L, Fig. 63. Lay off Fig. 65, as in the preceding case; square off the circumference, and divide as formerly in Fig. 64; then measure the length of the line at L, Fig. 63, where the seam is to be made, and set it off from the base-line A B, Fig. 65, on the line L at each end, and also in the middle. Then, measure the line I, Fig. 63, and mark it on its corresponding line I, Fig. 65. Measure again the line J, Fig. 63, and mark it on the corresponding lines J on each side of the lines I, Fig. 65. Then, measure K, Fig. 63, and set off its length on the lines K, Fig. 65, with the corresponding letters; and so on till all the lines are set off, when the curve can be drawn through the points as before.

In the particular case of a rectangular or square knee, the construction is illustrated by Figs. 66, 67, 68, and 69. Three templates are here

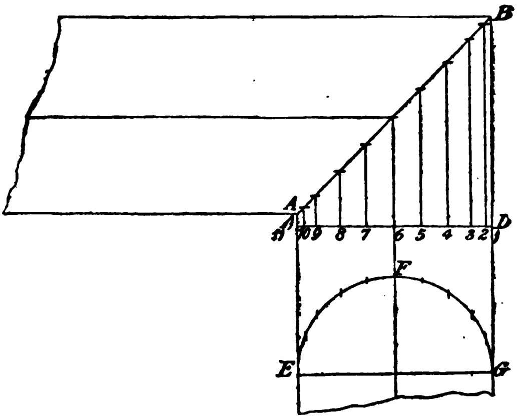


Fig. 66.—Development of a Square Knee.

shown, varying according to the position of the

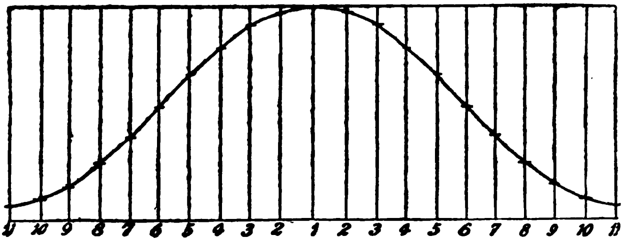


Fig. 67.—Square Knee. The Seam on the Shorter Side.

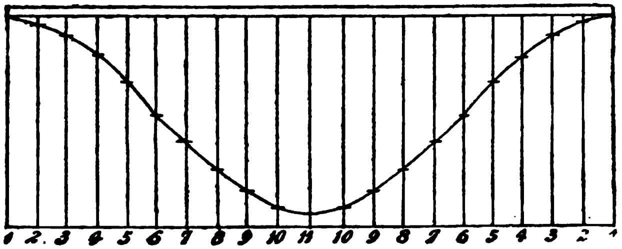


Fig. 68.—Square Knee. The Seam on the Longer Side.

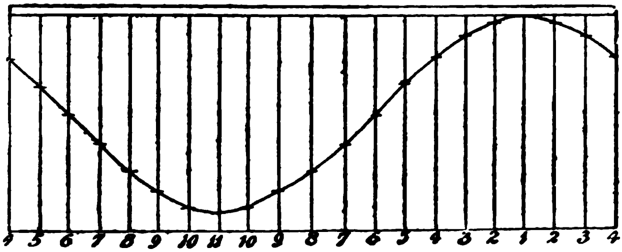


Fig. 69.—Square Knee. The Seam on No. 4 Line.

seam—at the shortest side, the longest side, or at an intermediate position.

To lay out a double, triple, or multifold bend, such as is sometimes preferred for small chimneys. First, lay down the form of the bend, as in Fig. 70, in which there are four junctions. Line off the junctions of the pieces, at A B, C D, E F, and G H. Divide C F and D E each into two equal parts at R and S. Draw R S, and bisect it; and on the centre thus found, describe the semicircle R T S. Divide the semicircle into any even number of equal parts, and through the points of division draw the lines 1, 2, 3, 4, &c., parallel to the lines C F and D E. Lay out the circumference of the plate, as in Fig. 71, 72, or 73; divide the circumference A B in these figures into twice as many

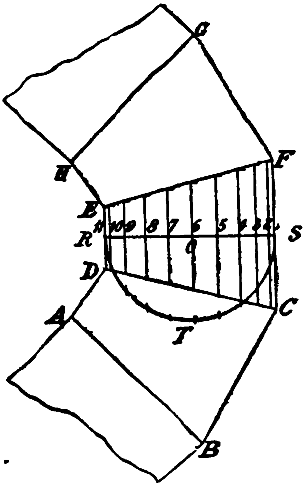


Fig. 70.—Development of a Double, Triple, or Multifold Bend.

parts as there are in the semicircle, Fig. 70, and through the points of division draw the lines 1, 2, 3, 4, &c., at right angles to the centre line A B. Then consider where the seam is to be located. If it is to be on the shortest side of the plate, the plate will be of the form of Fig. 71. If it is to be on the longest side, it will be in the form of Fig. 72; and if the seam is to be at any other place in the circumference, the height at that place is to be laid down at the ends of the plate, and from one or both ends of the plate the other heights are set off on the plate consecutively. Suppose, for instance, the seam is to be on No. 4 line in Fig. 70; then, from the centre line R S, Fig. 70, its height is measured, between the lines R S and E F, and this measurement is laid down at

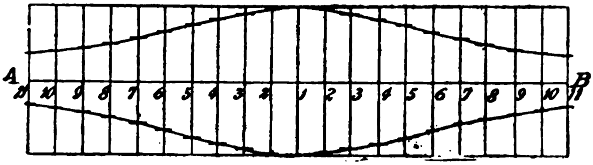


Fig. 71.—Multifold Bend. The Seam on the Shorter Side.

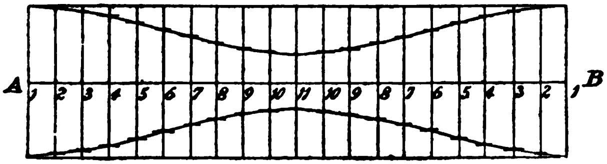


Fig. 72.—Multifold Bend. The Seam on the Longer Side.

each end of the centre line A B, Fig. 73, correspondingly marked 4. Next, measure in the same way, and lay down, Nos. 3, 2, 1, 5, 6, 7, &c., in Fig. 73, then draw the curve by means of a lath, as before described.

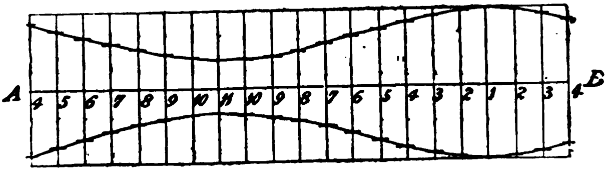


Fig. 73.—Multifold Bend. The Seam on Line No. 4.

To lay out the junction of two cylinders of equal diameters, one being penetrated by the other.—This is not a very common construction in boilermaking; but there are boilers formed something like the locomotive, by joining a cylinder to the back of a vertical donkey boiler as in Fig. 74.

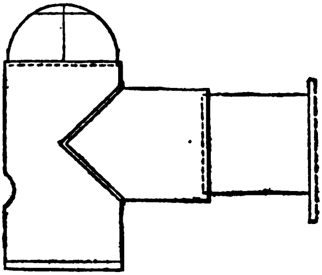


Fig. 74.—Junction of Two Cylinders of Equal Diameter. Donkey Boiler.

First of all, draw a circle to the diameter of the boiler or first cylinder, as A B C, Fig. 75; draw the diameter A B, and the lines A E and B D parallel to the centre line O C; divide the semicircle A C B into any even number of equal parts and through the points of division draw the lines 1, 2, 3, 4, &c., parallel to the sides B D and A E; then draw the line E D parallel to A B, at any convenient distance, and you have done all the drawing required in Fig. 75. Now lay out the circumference of the plate B B, Fig. 76 or 77, and having done so, set off the height B D, Fig. 75, in Figs. 76 and 77, to A and A, and draw the parallels A A. Divide the line A A or the line B B into twice as many equal parts as there are in the semicircle in Fig. 75, and through the points of division draw the lines 1, 2, 3, 4, 5, &c., parallel to the centre line C D, as in Fig. 76, if the seam is to be on the longer side of the plate; or, as in Fig. 77, if the seam is to be on the shorter side of the plate. Measure the length of the line 2 on Fig. 75, from the line E D to where it touches the semicircle A C B, and set off the length from the line

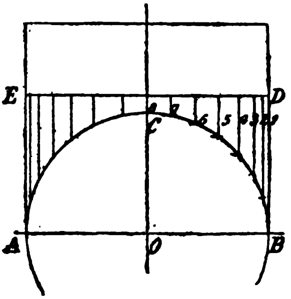


Fig. 75.—Development of Two Cylinders of Equal Diameter, one penetrated by the other.

A A, Fig. 76 or 77, on the perpendicular line correspondingly numbered. Measure the next line, 3, Fig. 75, in the same manner, and set it off on the corresponding perpendicular line in Figs. 76 or 77. Measure the rest of the lines in Fig. 75 in the same manner, and set them off on the corresponding lines in Fig. 76 or 77. Having thus obtained all the heights, either make a template for them, or bend a thin stick to skirt the heights, when a line can be drawn through the points with the draw-point. If the one cylinder is to be flanged to be riveted on the other, and if exactness is required, an allowance of about one thickness of the plate less is to be made for flanging it on the shorter side than on the longer side. The reason of this difference is that in flanging the shorter side to a right angle, a gain equal to the

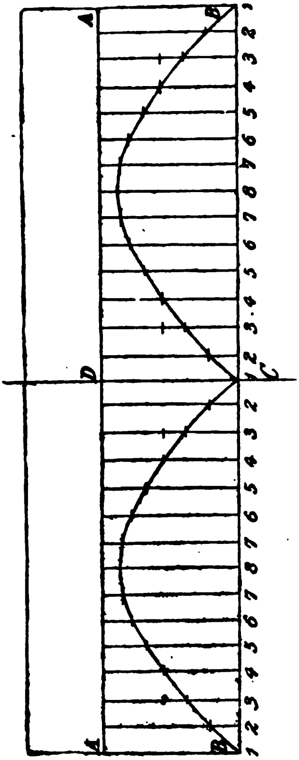


Fig. 78.—Two Cylinders. Seam on the Longer Side.

thickness of the plate is made; but on the longer side the gain is nothing, because there it is nearly straight; therefore, the flange may be cut by one thickness of the plate less, at the shorter side, the difference running out gradually till the flange gains the full breadth at the longer side. In practice, this gradation is seldom observed, because the extra width of flange gained in bending gives the riveters better access to the work if the holes are put in accordingly.

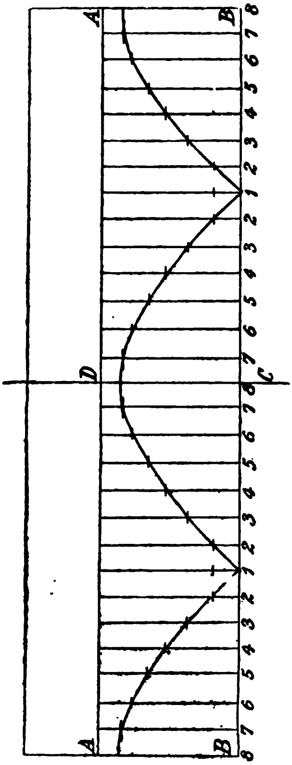


Fig. 77.—Two Cylinders Seam on the Short Side.

To lay out the rake of the funnel of a steamship.—First, lay down the diameter of the funnel as at Fig. 78, drawing the ends square, as A B, C D; then, if the rake is to be 1½ inches to the foot, and the diameter of the funnel 4 feet, set off 6 inches from B to E, and draw the line A E for the required angle of the funnel. At any convenient distance, describe two semicircles; divide these semicircles into any number of parts, endea-

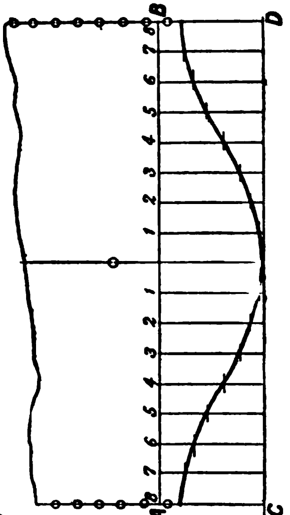


Fig. 79.—Funnel. Development.

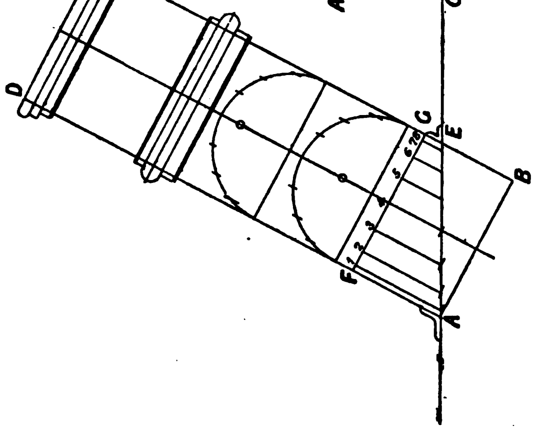


Fig. 78.—Funnel of a Steam-ship.

vouring, when counting the points of division, to have the centre line O O for an odd number; draw lines through these points, which only require to be produced from F G to A E. Next, lay down the plates from which to make the funnel, Fig. 79, and draw the line A B at the distance of A F, Fig. 78, from C D, Fig. 79. Divide these two lines into as many parts on each side of the centre line O, as there are parts in the full semicircle, Fig. 78, and draw lines through the points; then proceed to measure with the compasses the length of the line numbered 1 on Fig. 78, and transfer it to Fig. 79, marking its distance from the line A B on the line numbered 1 on each side of the centre O. Measure in the same way the lines 2, 3, 4, 5, 6, 7, 8, successively, transferring their distances to Fig. 79 on the lines bearing the corresponding numbers —always from the base line A B; and draw the curve through the points by means of a long thin lath, or by hand, if necessary.

As to the angle-iron junction-ring at the base of the funnel A E, the two sides make an obtuse angle with each other on the higher half of the funnel, graduating from the natural form of the angle-iron—a right angle—at the sides of the funnel in the centre line of the Fig. 78, to a maximum of obtuseness at A. On the lower half, the two sides of the angle-iron form an acute angle, attaining its maximum of acuteness at E. A "set" or small template is made for the angles at A and E respectively; and, with the aid of the sets, the ring is shaped at the forge. After having been shaped, the entire ring is usually made hot, and put in its place after it has cooled and shrunk a little, when it is close-fitted to the funnel as may be required.

To lay out the plates of a dome to be placed on the top of a boiler.—The rule is similar to the rule for the rake of a funnel; but, instead of drawing the line representing the deck or angle of the funnel, describe the arc of a circle, representing the top of the boiler on which the dome is to be placed, as in Fig. 80. To begin, draw the line O O; on this line with the radius of the boiler describe an arc of a circle; then, with the radius of the required dome describe the semicircles A O B and C E D; join A D and B C continued to F and G; divide the semicircles A O B and C E D into any number of parts, having an odd number for the centre point at E and O; and through these points draw the lines 1, 2, 3, 4, &c., which only require to be drawn from the line I J to the arc F G. It will be observed that the line I J is drawn at a convenient distance. If it were drawn touching the arc F G, the short lines on each side of the centre O O would not be so easily measured. Next, take the plate of which the dome is to be made, Fig. 81, and square out the required circumference. At one end of the plate, draw the two lines I J and F G at the distance asunder of I F, Fig. 80; divide these lines into as many parts on each side of the centre O, as are contained in the semicircle, Fig. 80; through these points draw perpendiculars. Then, measure the lines 1, 2, 3, 4, &c., Fig. 80, with the compasses, and from the line I J, Fig. 81, set off their distances on the

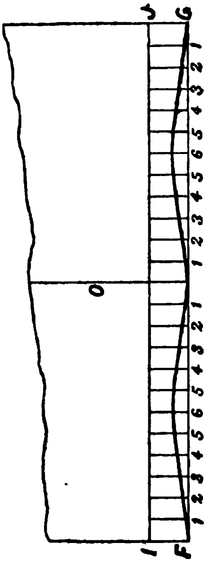


Fig. 81.—Steam Dome. Development of Junction.

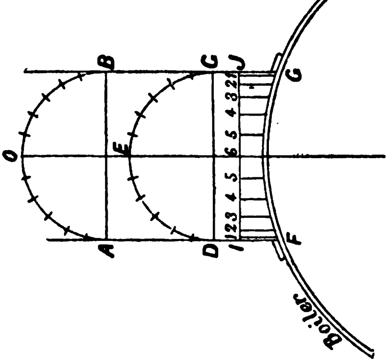


Fig. 80.—Steam Dome on a Boiler.

perpendicular lines correspondingly numbered.

The curve can then be drawn, as before, by hand, or by means of a thin lath of wood. If it is to be flanged, a second line can be drawn at the depth of the flange from the first curve line.

To lay out the plates of a dome to be placed on one side of a boiler.—Domes are of course round or cylindrical, as is shown by the semicircles in Fig. 82. Draw the radius of the boiler, and on it describe the diameter of the dome in the required position; describe the semicircles with the radius of the dome; divide as before; draw the lines 1, 2, 3, 4, &c., also as before. Then lay out the circumference of the dome required, Fig. 83, and draw the lines A B and C D at the distance apart E F, Fig. 82. Divide these, as before, into the same number of parts on each side of the centre, as there are in the semicircle. Then, with the compasses, measure the lengths of the lines 1, 2, 3, 4, &c., Fig. 82, and transfer them as before to Fig. 83, marking their distance from A B on the lines with the corresponding numbers. Draw the curve through the points, cut the plate, roll it, and when rolled it will fit exactly on the boiler. But, if the plate is not cut to the proper circumference, it will not fit so well as otherwise it would do.

If the seam is required to be on one side as at No. 6 line, in Fig. 82, work it the same way as is given in the directions for elbows or knees. From this it may be understood, that the seam may be placed anywhere on the circumference. A little practice will render the laying out easy and plain.

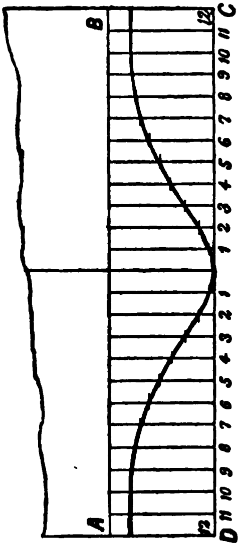


Fig. 83.—Steam Dome. Development of Junction.

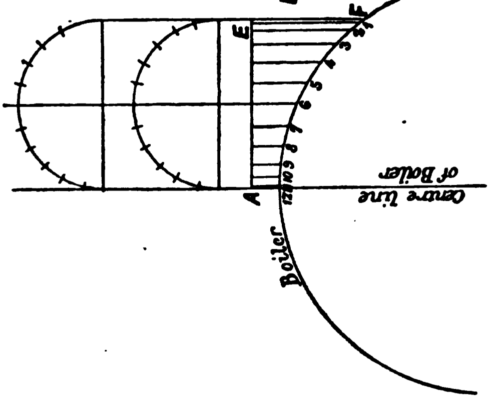


Fig. 82.—Steam Dome on a Boiler.

To lay out the connection-pipe between a boiler and a superheater, Fig. 84, the plan of which is given at Fig. 85 in the shape of an ellipse. The

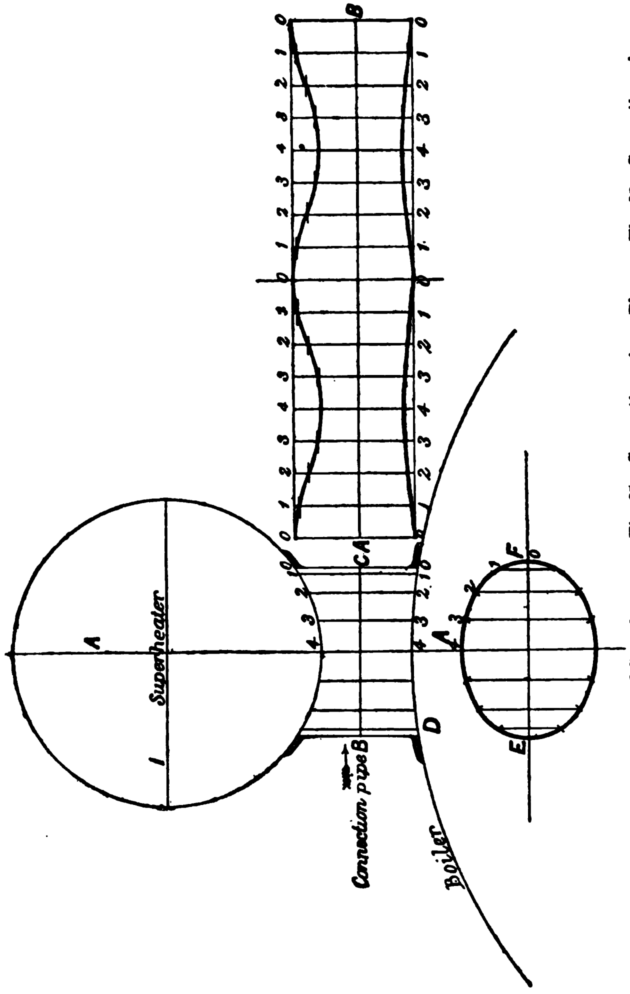
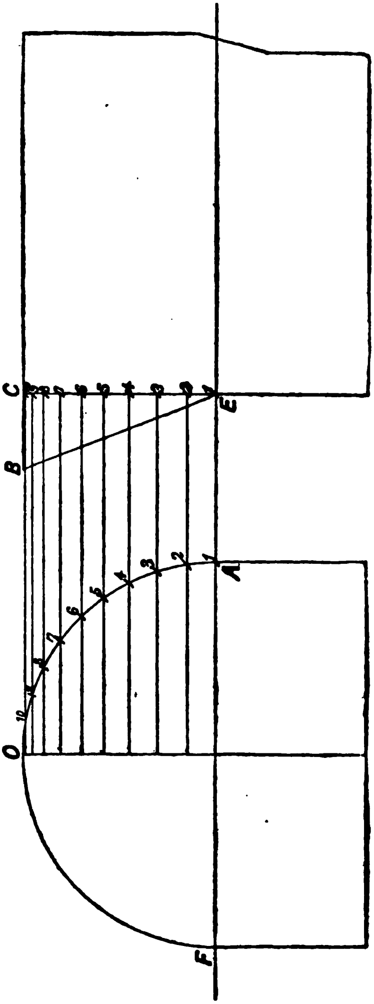


Fig. 84.—Connecting-pipe. Boiler and Superheater. Fig. 85.—Connecting-pipe. Plan. Fig. 86.—Connecting-pipe. Development.

method of doing this is very much the same as in the case of the domes, with this difference, that instead of drawing semicircles on which to divide the numbered lines, the ellipse is to be described and is to be divided into any number of parts, as before. First, draw the perpendicular line, A A; and on this line, at the required depth of the pipe apart, draw the arcs of circles to the radius respectively of the boiler and the superheater. Then, if the ellipse is to be placed across the boiler, draw the longer diameter of the connection-pipe half on each side of the centre line, A A; and, as there is not room to draw the ellipse in the space occupied by the connection-pipe, draw it just below, divide it into so many parts on each side of the centre, and line it through the connection-pipe. Draw the convenient line B C, and lay out the circumference of the plate which is to make the pipe, Fig. 86; divide it into the same number of equal parts on each side of the centre as are contained in the ellipse from E to F, Fig. 85; line these through the points, and draw the line A B, Fig. 86, at the distance B D, Fig. 84, from the edge of the plate. Measure the lines 1, 2, 3, 4, on each side of the line B C, and mark their distances from the line A B, Fig. 86, on their respective sides, on the lines having the corresponding numbers. The curve can then be drawn through the points, as formerly.

How to lay out the plate for the overhanging front of a boiler, as at B C E, Fig. 87.—If the top of the boiler is to be a semicircle or an arc of a circle, draw the form of the top, as at Fig. 87, which is the



Figs. 87, 87A.—Overhung Front of a Boiler.

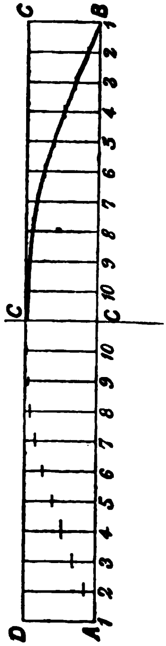
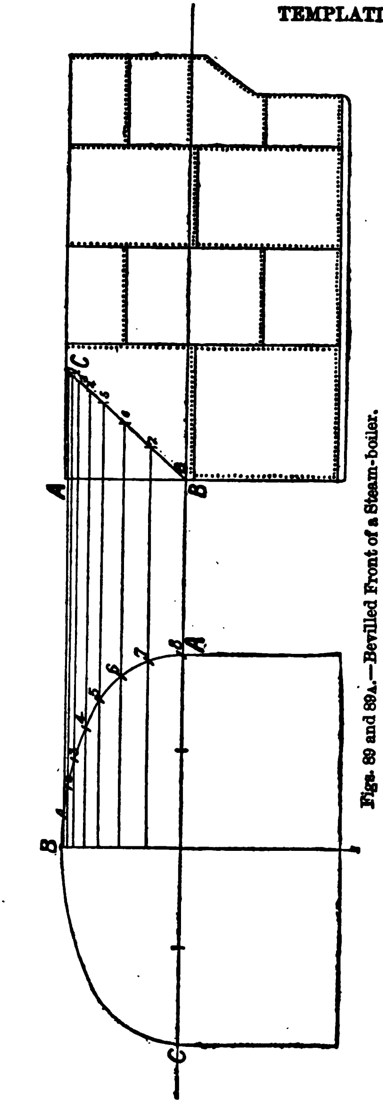


Fig. 88.—Overhung Front. Development.



Figs. 89 and 89A.—Bevilled Front of a Steam-boiler.

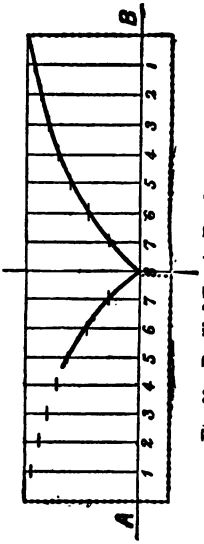


Fig. 90.—Bevilled Front. Development.

front elevation; parallel to that draw the overhang of the front as at Fig. 87A, showing the side elevation. Divide A O, into any number of equal parts, draw lines through these points parallel to the base line, F A, crossing the overhang, B C E. Next, lay out the circumference of the plate, Fig. 88, and from the base line, A B, draw the line D C at the distance of B C, Fig. 87. Divide out, on each side of the centre, C, the same number of parts as are contained in the arc, A O, Fig. 87; draw lines through the points parallel to the centre line, C C; measure the length of the line, No. 10, Fig. 87, between B E and C E, and transfer its length to the line having the corresponding number, Fig. 88, marking a point on the line on each side of the centre line, C C. Measure the rest of the lines, Fig. 87, in the same manner, and transfer them to the corresponding lines, Fig. 88; and draw the curve through the points.

If the top is elliptical, as at Fig. 89, and the corner, instead of hanging over, is cut off, as at B C, Fig. 89A, it is developed just in the same manner. Draw the front elevation, and divide it into any number of equal parts; draw the side elevation, and through it continue the lines from the front elevation; lay out the circumference, divide it as before, and transfer the lines from Fig. 89 to Fig. 90. Also, as before, in this case the narrowest part of the plate will evidently be at the centre.

How to draw the curve of a boiler top when the *versed sine or rise of the curve is given.*—Let A B be the rise, and C D the chord or span, E C being a round corner.

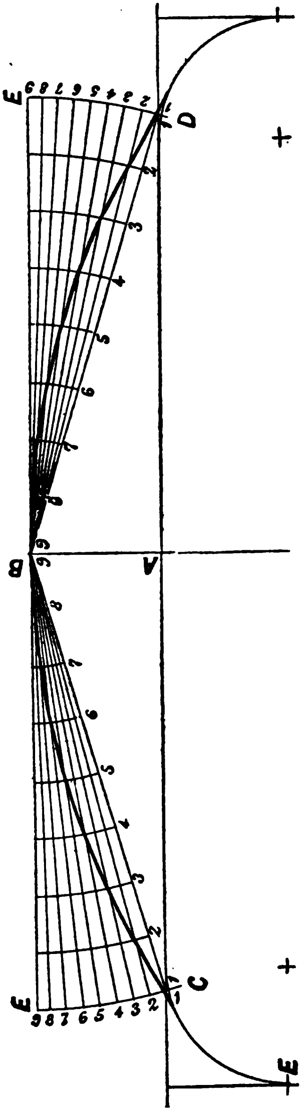


Fig 91.—Curve of a Boiler-top.

Join B C and B D; and divide B C and B D into any number of points or parts, 1, 2, 3, 4, &c. On B as centre, draw arcs through the points 1, 2, 3, 4, &c., on each side of the centre A B, and divide the arcs D E and C F into the same number of equal parts as B D or B C; draw lines from the centre B through the points in the arcs D E and C F. The intersections of these lines with the circular arcs will give points in the curve which may be drawn by means of a lath, or by hand if necessary.

To lay out the plates

for an egg-ended boiler, as Fig. 92.—First, lay

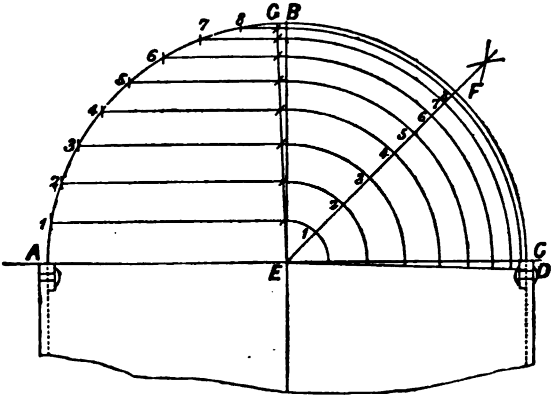


Fig. 92.—Egg-end of a Boiler.

out the semicircle or shape of the boiler end,

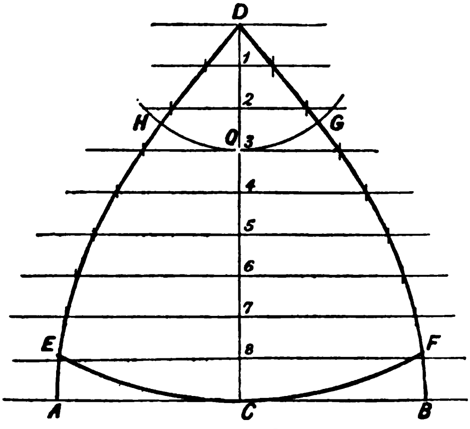


Fig. 93.—Egg-end. Development.

Fig. 92, and draw the line B E through the centre of the semicircle, thus dividing it in two. Next, divide the quarter circle A B into any number of equal parts, 1, 2, 3, 4, &c., and draw lines through the points of division parallel to the base line A E C; and, on the centre E with the radii of the terminations of the lines, 1, 2, 3, 4, &c., draw quarter circles respectively, as represented in the half-plan E, now being taken as the crown of the boiler when looking down upon it, instead of B when looking at the side of it. Then, in this case, the end is to be made in four plates. As B C is a quarter circle, and as it is desirable in this sort of work to work always from a centre, bisect the quarter circle B C at F, and join F E.

Proceed then to mark out the plate which is to make the end. Draw the base line A B, Fig. 93, bisect it, and raise a perpendicular at C; then reckon the length of plate necessary to make or go round the quarter circle, C B, Fig. 92, by measuring the diameter of the base, multiplying it by 3·1416, and dividing the product by 4 for the length of the quarter circle. Mark the length thus found, on the perpendicular from C, Fig. 93, at D, divide C D into the same number of parts as are contained in the quarter circle, A B, Fig. 92, and draw lines through the points parallel to the base A C B, and then set off the half of the length C D on each side of the centre line at C. It will be observed that A B, Fig. 93, has also to go round a quarter circle. Bisect the angle B E C, Fig. 92, by the line E F, and, from the centre F, set off the distance A C, Fig. 92, cutting the circle at

G D, and draw G E and D E. These additional lines are for the purpose of making up the loss that would otherwise occur in measuring straight across the arc B F, Fig. 92, instead of round the curve. Then, measure the length of the arc, No. 8, on Fig. 92, from the centre line, E F, to the line G E, and transfer its distance to Fig. 93 (marking it on each side of the centre) on the line having the corresponding number. Measure then each of the remaining arcs, 7, 6, 5, 4, &c., and transfer it to Fig. 93, on the corresponding line. The curves A D, B D, can then be drawn through the points. On the centre D, with radius D C, Fig. 93, the curve of the base can be drawn; or, more correctly, measure the distance C D round the curve from D to E and to F, as E D requires also to be of the length of a quarter circle.

Again, if there is to be a circular crown plate on the top, instead of the side plates running to the central point, mark off the length of the side plate required, from E and F to G and H, Fig. 93, also from C to O, on the centre line, when the curve can be drawn through the points.

This process can be verified by multiplying the breadth of the plate at given parts by 4; and multiplying the diameter of the semicircle, Fig. 92, at the corresponding parts, by 3·1416. If the two products agree, the work is right. Of course, it can be done at first in this way, by multiplying the diameter at certain places, as 1, 2, 3, 4, &c., Fig. 92, by 3·1416, and dividing by the number of plates of which it is to be made, and setting off half the product on the corresponding lines on each side of the centre line in Fig. 93.

Another way, sometimes employed, is to take once and a half the diameter of the boiler for the radius of the two sides and the bottom edge; and once and a half the diameter of the crown plate for the radius of the small end.

The top of the dome of a locomotive is drawn in the same way; except that the base is straight, it being made all in one plate, and the points gathered in after it is bent and welded up the sides. See Figs. 94 and 95.

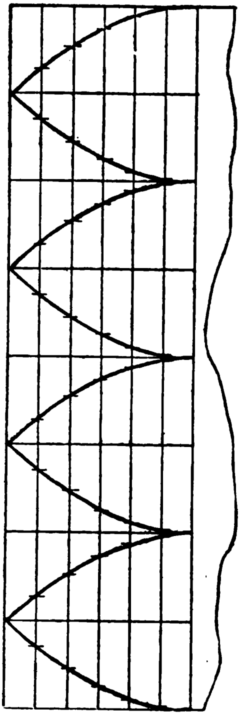


Fig. 95.—Steam Dome. Development.

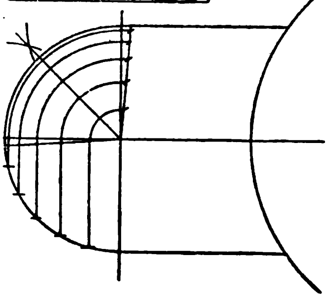


Fig. 94.—Steam Dome of a Boiler.

To draw the rise of the plates of a frustum of a cone without continuing the lines at the sides to a point, or when the point is not accessible.—As, for instance, the fire-box of a donkey boiler, or the plates of a land boiler when it is made as per diagram, Fig. 96.

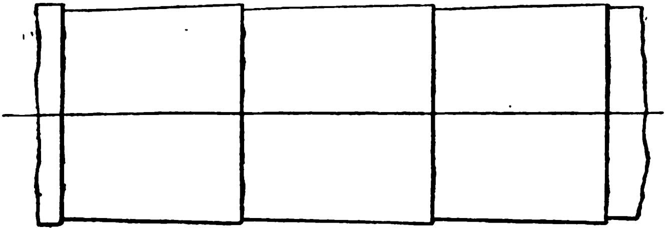


Fig. 96.—Conical Lapped Plates of a Boiler.

Great difficulty is sometimes experienced in marking the curve or camber on plates, when there is only a slight taper, and when, consequently, the sides would run to a great length before they meet. The mode of finding the curve or camber, which we now proceed to give, is the simplest, the quickest, and the only correct method, that has yet been put forward for the use of boilermakers or metal-plate workers; the discovery and correct application of which is due to Mr. R. Fyfe, Cowlairs Works, Glasgow.

Let A B C D, Fig. 97, be the shape of the cone for which it is required to describe the cambers A E B and D F C. Proceed by placing one leg of the compasses at H, when, if it is exactly central, between A D and the centre line G F, it should just touch the lines A D and G F in describing a circle; then with H (the centre of the circle) as a centre, and the radius H A, describe an arc of a circle, cutting the centre line E G F, at E, when the distance intercepted between G and E will be the rise. On the same centre, with H D as radius, describe an arc of a circle, cutting the centre line again at F, when the space intercepted between J and F will be the rise of the shorter curve D F C. If the working be correct, the distance between F and E should equal D A.

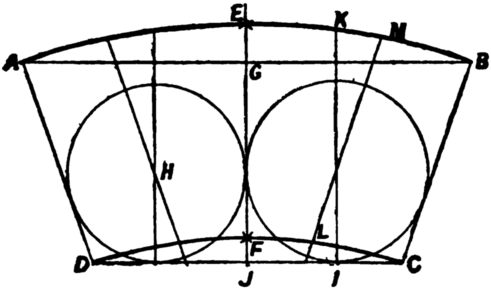


Fig. 97.—Conical Plates. Development.

When it is required to point out definitely the centre H on which the point of the compasses are placed, proceed thus. Draw a line I K parallel to G F at the distance of a little less than half of G B from G F; then from C B at the same distance, draw the line L M parallel to C B. The intersection of these two lines will be the centre of the circle H.

Again, to be accurate in the drawing of the curve by hand, there ought to be found more points than the one in the centre of the curve. To accomplish this, divide the lines A B and C D, Fig. 98, each into the same number of equal parts, and draw lines through the points as shown. When this is done, it will be seen that the lines are all converging towards one point at the narrowest side of the figure, D C. Therefore, each of those parts into which it has been divided is itself taper; and, by means of the construction already illustrated in Fig. 97, a point in the curve can be marked on each of the lines of division as before.

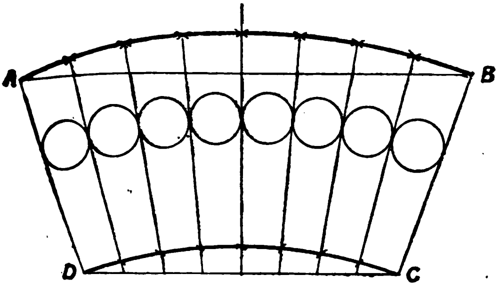


Fig. 98.—Conical Plates. Development.

We will now develop the circumference of the cone as at Fig. 99; that is, if the circumference is to be made up in one plate. It will be seen that the Figs. 97 and 98 merely represented the diameter of the cone, or side view; and that the curve will require to be extended over more than three times the diameter, so that we have to describe another cone on each side of the one previously drawn. To do so, we will proceed as follows. From E as a centre and radius of E to B, describe an arc of a [illegible] D; the same again from F as a centre and

F C as radius, describing an arc of a circle at A. Then, with the same radius and B and C respectively as centres, describe an arc of a circle at G,

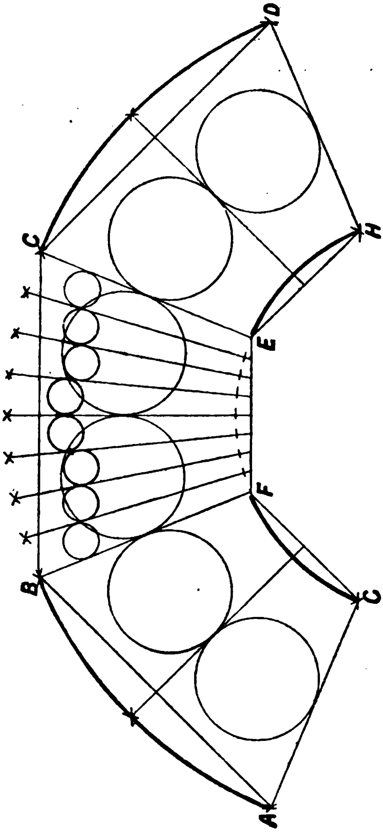
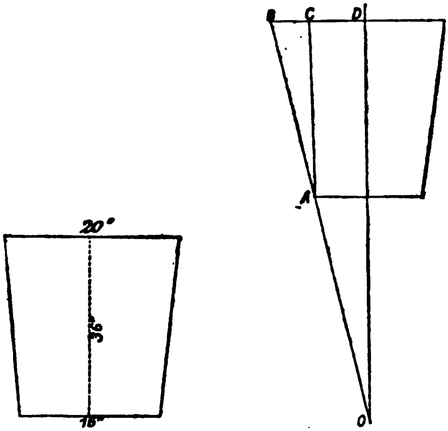


Fig. 99.—Conical Plates. Development.

and another at H; next, on E and F respectively as centres and radius E F, describe arcs of a circle, cutting the others at G and H; again, on B and C as centres and radius, B C, describe arcs, cutting the others at A and D; join the intersections thus formed with the middle cone first drawn, when we will have three cones, each equal in every respect to the other, and also four points in the curve A B C D, which can be depended on. Then, by making a small template to the curve already described on the middle cone according to the method shown in Figs. 97 and 98, and applying it to the points A B, and C D, we can draw it with a pencil or draw-point, which will save a little time. The lesser curve, of course, is done in the same manner.

To find the rise and radius of a cone by calculation.—Suppose the frustum of a cone as per diagram, Fig. 100, the larger diameter of which is 20 inches,



Figs. 100 and 101.—Radius and Rise of a Cone.

the less diameter 16 inches, and the depth 36 inches; to find the radius, or, in other words, how far the side lines will run before they meet.

Divide the greater diameter by the difference between the greater and less diameters, and multiply the depth by the product. The answer will be the radius in inches, the dimensions being given in inches. Thus: 20 — 16 = 4 : then 20 ÷ 4 = 5, and 36 × 5 = 180 inches ÷ 12 = 15 feet. Another rule is:—to say, by proportion, as half the difference between the two diameters is to the radius of the larger diameter, so is the slant depth of the plate to the radius required; thus 20 — 16 = 4 ÷ 2 = 2; then half the radius of the larger diameter, being 10 inches, and the depth 36 inches, it stands thus: 36 × 10 = 360 ÷ 2 = 180 as before, or say, by proportion, B C : B D :: B A : B O.

Next, to find the rise of the cone. Square the radius B D of the larger diameter and subtract it from the square of the radius B O; the square root of the product will be the length of the perpendicular O D; subtract O D from O B, and the remainder will be the height of the rise.

TABLE OF STEAM-TIGHT RIVETED JOINTS FOR BOILERS.

Thickness of plate.	Dia. of rivet.	Pitch.		Breadth of Lap.		Distance between centre lines of rows of holes in double riveting.
		Single riveted centres of holes.	Double riveted centres of holes.	Single riveted.	Double riveted.	
Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
$\frac{3}{16}$	$\frac{3}{8}$	1	$1\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{7}{8}$	$\frac{3}{4}$
$\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{5}{8}$	$2\frac{1}{2}$	1
$\frac{5}{16}$	$\frac{9}{16}$	$1\frac{1}{2}$	2	$1\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{1}{8}$
$\frac{3}{8}$	$\frac{5}{8}$	$1\frac{5}{8}$	$2\frac{1}{4}$	2	$3\frac{1}{8}$	$1\frac{1}{4}$
$\frac{7}{16}$	$\frac{11}{16}$	$1\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{8}$	$3\frac{3}{8}$	$1\frac{3}{8}$
$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{7}{8}$	$2\frac{5}{8}$	$2\frac{3}{8}$	$3\frac{3}{4}$	$1\frac{1}{2}$
$\frac{9}{16}$	$\frac{13}{16}$	2	$2\frac{7}{8}$	$2\frac{1}{2}$	4	$1\frac{5}{8}$
$\frac{5}{8}$	$\frac{7}{8}$	$2\frac{1}{4}$	$3\frac{1}{8}$	$2\frac{3}{4}$	$4\frac{3}{8}$	$1\frac{3}{4}$
$\frac{11}{16}$	$\frac{15}{16}$	$2\frac{3}{8}$	$3\frac{1}{4}$	3	$4\frac{3}{4}$	$1\frac{7}{8}$
$\frac{3}{4}$	1	$2\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{8}$	5	2
	D = dia. of rivet.	$2\frac{1}{2}$ D	$3\frac{1}{2}$ D	3 D	5 D	2 D

There is a margin of $\frac{1}{16}$ inch in some of the values. It was thought better to let it go thus than to trouble with $\frac{1}{16}$ inch or $\frac{1}{32}$ inch in the columns of figures.

The table is very suitable for all classes of boilers. The smaller sizes of rivets, from $\frac{3}{8}$ inch to $\frac{9}{16}$ inch, are seldom used in boilers; but they are very well proportioned for oil-tanks or for water-tanks.

CHAPTER VII.

POWER AND PROPORTIONS OF STEAM BOILERS.

CORNISH AND LANCASHIRE BOILERS.

A VERTICAL or upright surface has, it is considered, only half the evaporative value of a horizontal surface. That is, for instance, the sides of a locomotive fire-box are only half as effective per square foot as the flat top of the box.

In tubes and flues the effective surface measured on the circumference is 1¼ times the diameter.

One cubic foot of water evaporated per hour is equivalent to one nominal horse-power. Thus, a boiler that boils or evaporates 20 cubic feet of water per hour is a boiler of 20 nominal horse-power.

An easy approximate rule for the nominal horse-power is to multiply the length of the boiler by the diameter, in feet, and divide by 6: the quotient is the nominal horse-power.

Another rule.—Multiply the heating surface in square yards by the fire-grate surface in square feet; the square root of the product is the nominal horse-power.

The fire-grate surface is equal to the square of the nominal horse-power, divided by the heating surface in square yards. That is to say, square the nominal horse-power, and divide it by the heating surface in square yards; the quotient is the fire-grate surface in square feet.

Or, 1 square foot of fire-grate per nominal horse-power.

The heating surface.—Square the nominal horse-power, and divide that by the fire-grate surface in square feet; the quotient is the heating surface in square yards.

Or, 1 square yard of heating surface per nominal horse-power.

Capacity of Boiler.—One cubic yard of boiler capacity per nominal horse-power.

Steam-room should be about eight times the contents of the cylinder of the engine supplied with steam by the boiler.

One cubic foot of water equals 6·232 gallons.

LOCOMOTIVE BOILERS.

To find the quantity of water evaporated in cubic feet per hour; that is, the nominal horse-power.—Square the area of the heating surface in square feet, and divide by the area of the fire-grate in square feet; multiply the quotient by ·0022; the product is the nominal horse-power.

To find the area of the heating surface.—Multiply the nominal horse-power by the area of the grate in square feet; extract the square root of the product, and multiply the root found by 21·2;

the product is the area of the heating surface in square feet.

To find the area of the fire-grate surface.—Square the area of the heating surface in square feet, divide it by the number of nominal horse-power, or the cubic feet of water evaporated per hour. The quotient multiplied by ·0022 equals the area of the fire-grate surface in square feet.

Or, divide the area of the heating surface in square feet by 65; the quotient will be the area of the fire-grate in square feet, nearly.

TUBULAR BOILERS OR MARINE BOILERS.

Each nominal horse-power requires the evaporation of 1 cubic foot of water per hour; 12 square feet of heating-surface, only $\frac{3}{4}$ of the whole tube-surface being taken as effective; and 30 square inches of fire-grate per nominal horse-power. The sectional area of the tubes to be about $\frac{1}{6}$ of the fire-grate.

GENERAL RULE FOR ALL CLASSES OF BOILERS.

Twelve square feet of heating-surface, and $\frac{3}{4}$ square foot of fire-grate, per nominal horse-power, are very good proportions. A boiler that is large enough to do its work is better than one that is deficient in surface. When the proportions of a boiler are not large enough, it requires to be forced to get the work out of it, and this can only be done at expense for fuel.

RULES FOR SAFETY-VALVES.

1. *To find the distance from the fulcrum at which a given weight is to be placed on the lever, in order to balance a given pressure in the boiler.*—Multiply the steam-pressure on the whole area of the safety-valve by the distance of the centre of the valve from the centre of the fulcrum. Multiply the dead weight of the lever and the valve by half the length of the lever. Subtract this product from the first product, and divide the remainder by the given weight, supposed to be a cast-iron ball. The quotient is the required distance of the weight from the fulcrum.

Suppose that the entire pressure of steam on the valve is 24 lbs.; that the centre of the valve is 2 inches from the centre of the fulcrum; and that the weight of the ball is 3 lbs. The first product is $24 \times 2 = 48$. The length of the lever is 16 inches, and the united weight of the lever and valve is 4 lbs., and the second product is $(16 \div 2 =)\ 8 \times 4 = 32$. Then $48 - 32 = 16$; and $16 \div 3 = 5\frac{1}{3}$ inches, the required distance of the centre of the ball from the centre of the fulcrum.

2. Given the whole pressure on the valve, its distance from the fulcrum or point of the lever, the length of the lever, and the weight of the lever; to find the weight of the ball to hang on that given length in order that the steam may blow off at the given pressure. Multiply the whole pressure on the valve by its distance from the fulcrum; from this

product subtract the product of the weight of the lever and valve, multiplied by one-half of the length of the lever, then divide the remainder by the whole length of the lever. The quotient is the weight of the ball in lbs.

The pressure in the boiler is 60 lbs. per square inch on the valve, the centre of the valve is 2 inches from the fulcrum, the weight of the valve and lever is 10 lbs., and the length of the lever is 14 inches.

Suppose the opening in the boiler to be 2 inches in diameter, then 2 squared = 4 ; and 4 multiplied by ·7854 = 3·1416 square inches, the area of the valve. The whole pressure on the valve is 60 lbs. × 3·1416 = 188·496 lbs. The distance of the centre of the valve from the fulcrum is 2 inches, and 188·496 multiplied by 2 = 376·992. From this product, subtract the product of the weight of the valve and lever (10 lbs.) by the half-length of lever, 7 inches (total length being 14 inches) or 10 × 7 = 70. Then 376·992 − 70 = 306·992 ; and 306·922 divided by the length of lever, or 14 inches = 21·928 lbs., the required weight of ball.

3. Given the resistance, or weight of ball, the weight of the lever, the distance of the power from the fulcrum; the distance of the resistance from the fulcrum; to find the power or pressure on the valve. Multiply the resistance, or weight of the ball, by the length of the lever. To the product add the product of the weight of the lever and valve by the half-length of lever, and divide the

sum by the distance of the power from the fulcrum. The quotient is the pressure on the valve in lbs.

Suppose the ball weighs 21·928 lbs., the length of the lever 14 inches, the weight of the lever and valve 10 lbs., the distance of the power from the fulcrum 2 inches; then (21·928 × 14 = 306·992) + (10 × 7 = 70) = 376·992; and 376·992 ÷ 2 = 188·496 lbs., the whole pressure on the valve. This pressure divided by the area of the valve in square inches, gives the pressure per square inch on the boiler.

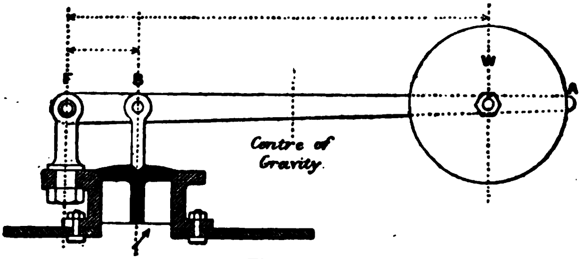


Fig. 102.

4. *Given the whole pressure and its distance from the fulcrum, the load or ball and its distance from the fulcrum, to find the weight of the lever.*—Multiply the whole pressure by the distance of the centre of the valve from the fulcrum; from this product subtract the product of the weight of the ball multiplied by the length of the lever; divide the remainder by the half-length of the lever. The quotient is the weight of the lever in lbs.

Let the pressure be 188·496 lbs., distance of valve from fulcrum 2 inches, weight of 21·928 lbs., length of lever 14 inches. Required the weight of the lever. ($188{\cdot}496 \times 2 = 376{\cdot}992$) and ($21{\cdot}928 \times 14 = 306{\cdot}992$). Subtracting the second from the first product, $376{\cdot}992 - 306{\cdot}992 = 70$; and $70 \div 7 = 10$ lbs., the weight of the lever and valve.

NOTE.—These rules, though not exact, are sufficiently approximate for ordinary use.

CHAPTER VIII.

STRENGTH AND WEIGHT OF IRON.

TENSILE STRENGTH OF BARS AND PLATES.

BREAKING tensile strength of bar-iron (average) per square inch of section:—

Best Yorkshire, 28·3 tons.
Best Staffordshire, 26·3 tons.
Best Lanarkshire, 24·8 tons.

Breaking tensile strength of boiler plate (average) per square inch:—

Best Yorkshire plate, 25 tons.
Crown, or best Staffordshire plate, 20 tons.
Glasgow best best boiler plates, 24 tons.

Multiply the tensile strength of the plate by 0·7; the product is the strength of the joints in double-riveted boilers.

For single-riveted joints multiply by 0·56 for the strength of joint.

The working strain should not be more than ⅙ of the strength of joint.

LOWMOOR RIVET-IRON.

The breaking tensile strength of rivet-iron is equal to 26 tons per square inch of its section.

The shearing strength of Lowmoor rivets is equal to 18 times the square of the diameter in inches.

WORKING STRENGTH OF BOILERS.

To find the thickness of plate necessary for cylindrical boilers to stand a given pressure, when the diameter is given:—

Yorkshire Plates.—Multiply the given pressure by the given diameter in inches, and divide by 15,600, for the thickness in inches and parts of an inch of plate double-riveted; or, divide by 12,400 for plate single-riveted.

Best Staffordshire Plate.—Multiply the given pressure by the given diameter in inches, and divide by 12,400, for the thickness in inches of plate double-riveted; or, divide by 10,000 for plate single-riveted.

Ordinary Iron Plate.—Divide by 7,400 for double-riveted plate; or, by 6,000 for single-riveted plate.

To find the pressure at which a cylindrical boiler may be safely worked, the diameter and the thickness of plates being given:—

Yorkshire Plates.—Multiply twice the thickness of the plate in inches by 7,800 for double-riveted joints, or by 6,200 for single-riveted joints, and divide by the diameter of the boiler in inches. The quotient is the working pressure in lbs. per square inch.

Best Staffordshire Plates.—Multiply twice the thickness in inches by 6,200 for double-riveted joints; or by 5,000 for single-riveted joints; and divide by the diameter in inches; the quotient is the working pressure in lbs. per square inch.

Ordinary Iron.—Multiply by 3,700 for double-riveted joints; or by 3,000 for single-riveted joints.

The quotient is the working pressure in lbs. per square inch.

STAYING FLAT SURFACES IN BOILERS.

Square the thickness of the plate in inches (that is, multiply the thickness of the plate by itself), and multiply the product by 16,000; then, divide this product by the pressure in lbs. per square inch of the boiler, and the square root of the quotient is the proper distance of stays apart from centre to centre, in inches.

Suppose the plate to be 0·5 inch or $\frac{1}{2}$ inch thick, and the pressure 20 lbs. per square inch. Then $\cdot 5 \times \cdot 5 = \cdot 25$; and $\cdot 25 \times 16{,}000 = 4{,}000$; and $4{,}000 \div 20 = 200$; the square root of 200 is 14·14 inches, or $14\frac{1}{8}$ inches from centre to centre of stays.

Having got the distance apart of the stays, what ought to be the thickness of the stays? Multiply the area supported by the stay in square inches by the pressure in lbs. per square inch, and divide by 9,000 if the stay is thickened where the screw is cut, or by 6,000 if the screw is cut in the body of the stay. The square root of the quotient is the thickness required.

Thus, taking the same data, $14{\cdot}14^2 = 159{\cdot}9396$; and this $\times\ 20 = 3{,}198{\cdot}7920$, which divided by $6{,}000 = \cdot 5331$. The square root of ·5331 is ·73 inch. Reducing this decimal to ordinary fractions, $\cdot 73 \times 8 = 5{\cdot}84$ eighths of an inch; and $84 \times 2 = 1{\cdot}64$ sixteenths; and $\cdot 64 \times 2 = 1{\cdot}28$ thirty-seconds. So, the diameter of the stay required is $\frac{5}{8}\ \frac{1}{16}\ \frac{1}{32}$ inch.

WEIGHT OF WROUGHT-IRON PLATES AND BARS.

Thickness of plates in $\frac{1}{8}$ parts of an inch multiplied by 5 = lbs. weight per square foot.

Thickness of plates in $\frac{1}{16}$ parts of an inch multiplied by 2·5 = lbs. weight per square foot.

Area of section of flat bars (in inches) multiplied by 3·33 = lbs. weight per foot of length.

Area of section of flat bars in $\frac{1}{8}$ parts of an inch multiplied by ·052 = lbs. weight per foot of length.

Diameter of round iron in inches squared multiplied by 2·64 = lbs. per foot of length.

Multiply the weight of wrought iron by 1·15 for the weight of copper.

Multiply the weight of wrought iron by ·93 for the weight of cast iron.

Multiply the weight of wrought iron by 1·02 for the weight of steel.

Multiply the weight of wrought iron by 1·09 for the weight of brass.

Examples.—Given a plate 6 feet long, 3 feet broad, and $\frac{3}{8}$ inch thick; to find the weight. The surface is equal to 6 × 3 = 18 square feet; then $\frac{3}{8} \times 5 = 15$ lbs. per square foot; and 15 lbs. × 18 square feet = 270 lbs., or 2 cwt. 1 qr. 14¼ lbs., the weight of the plate.

Given a flat bar 1 foot long, 3 inches broad, and ½ thick, to find the weight. Sectional area, 3 × ·5 = 1·5 square inch; and 3·33 × 1·5 = 5 lbs., the weight of the bar.

Given a round bar 1½ inches diameter; to find the weight per foot of length. The square of the diameter is 1·5 × 1·5 = 2·25; and 2·25 × 2·64 = 5·94 lbs. per foot of length.

WEIGHT OF FLAT BAR IRON FROM 1 × ¼ INCH TO 6 × 1 INCHES; AND FROM 1 FOOT TO 10 FEET IN LENGTH.

Breadth and Thickness.	Weight in Pounds.									
	1 Foot.	2 Feet.	3 Feet.	4 Feet.	5 Feet.	6 Feet.	7 Feet.	8 Feet.	9 Feet.	10 Feet.
Inches.										
1 × ¼	·83	1·66	2·49	3·32	4·15	5·00	5·81	6·64	7·50	8·33
1 × ⅜	1·25	2·50	3·75	5·00	6·25	7·50	8·75	10·00	11·30	12·50
1 × ½	1·67	3·33	5·00	6·67	8·33	10·00	11·70	13·30	15·00	16·70
1⅛ × ¼	·94	1·88	2·81	3·75	4·69	5·63	6·56	7·50	8·44	9·40
1⅛ × ⅜	1·40	2·80	4·20	5·60	7·00	8·40	9·80	11·30	12·70	14·10
1⅛ × ½	1·88	3·75	5·62	7·50	9·38	11·30	13·10	15·00	16·90	18·80
1⅛ × ⅝	2·34	4·68	7·02	9·38	11·70	13·10	16·38	18·80	21·10	23·40
1¼ × ¼	1·04	2·08	3·12	4·16	5·20	6·24	7·28	8·32	9·36	10·40
1¼ × ⅜	1·56	3·12	4·68	6·25	7·80	9·38	10·90	12·50	14·10	15·60
1¼ × ½	2·08	4·16	6·24	8·32	10·40	12·48	14·56	16·64	18·72	20·80
1¼ × ⅝	2·60	5·20	7·80	10·40	13·00	15·60	18·20	20·80	23·40	26·00
1¼ × ¾	3·12	6·24	9·36	12·48	15·60	18·72	21·84	24·96	28·08	14·20
1⅜ × ¼	1·15	2·28	3·44	4·58	5·73	6·87	8·02	9·12	10·30	11·50

1⅜ × ⅜	1·72	3·44	5·16	6·87	8·59	10·30	12·00	13·68	15·50	17·20
1⅜ × ½	2·29	4·57	6·87	9·17	11·50	13·80	16·00	18·30	20·60	22·90
1⅜ × ⅝	2·87	5·74	8·61	11·48	14·35	17·22	20·09	22·96	25·83	28·70
1⅜ × ¾	3·44	6·88	10·30	13·80	17·20	20·60	24·10	27·50	30·90	34·40
1½ × ¼	1·25	2·50	3·75	5·00	6·25	7·50	8·75	10·00	11·30	12·50
1½ × ⅜	1·88	3·74	5·61	7·48	9·35	11·02	13·09	15·00	16·83	18·80
1½ × ½	2·50	5·00	7·50	10·00	12·50	15·00	17·50	20·00	22·50	25·00
1½ × ⅝	3·12	6·24	9·38	12·48	15·60	18·72	21·84	25·00	28·08	31·20
1½ × ¾	3·75	7·50	11·30	15·00	18·80	22·50	26·30	30·00	33·80	37·50
1½ × ⅞	4·38	8·75	13·10	17·50	21·90	26·30	30·60	35·00	39·40	43·80
1⅝ × ¼	1·35	2·70	4·05	5·40	6·75	8·15	9·48	10·80	12·20	13·50
1⅝ × ⅜	2·03	4·06	6·09	8·13	10·15	12·18	14·21	16·24	18·27	20·30
1⅝ × ½	2·71	5·42	8·13	10·84	13·55	16·26	19·00	21·60	24·39	27·10
1⅝ × ⅝	3·38	6·76	10·20	13·52	16·90	20·28	23·60	27·04	30·50	33·80
1⅝ × ¾	4·06	8·13	12·20	16·30	20·30	24·40	28·40	32·50	36·60	40·60
1⅝ × ⅞	4·73	9·46	14·19	19·00	23·70	28·38	33·11	37·84	42·70	47·30
1¾ × ¼	1·46	2·90	4·37	5·80	7·25	8·70	10·15	11·60	13·05	14·60
1¾ × ⅜	2·19	4·38	6·57	8·76	10·95	13·14	15·33	17·52	19·71	21·90
1¾ × ½	2·91	5·82	8·73	11·64	14·55	17·46	20·37	23·28	26·19	29·20
1¾ × ⅝	3·64	7·28	10·92	14·56	19·20	21·84	25·48	29·12	32·76	36·40
1¾ × ¾	4·38	8·75	13·08	17·44	21·90	26·30	30·60	35·00	39·40	43·80

Breadth and Thickness.	Weight in Pounds.									
	1 Foot.	2 Feet.	3 Feet.	4 Feet.	5 Feet.	6 Feet.	7 Feet.	8 Feet.	9 Feet.	10 Feet.
Inches.										
1¾ × ⅞	5·09	10·18	15·27	20·36	25·45	30·54	35·63	40·72	45·81	50·90
1⅞ × ¼	1·56	3·12	4·68	6·24	7·80	9·36	10·92	12·48	14·10	15·60
1⅞ × ⅜	2·33	4·66	6·99	9·32	11·65	14·10	16·31	18·64	21·10	23·40
1⅞ × ½	3·12	6·24	9·36	12·48	15·60	18·72	21·84	24·98	28·08	31·30
1⅞ × ⅝	3·90	7·80	11·70	14·60	19·50	23·40	27·30	31·20	35·10	39·10
1⅞ × ¾	4·68	9·38	14·10	18·72	23·40	28·08	32·76	37·44	42·12	46·90
1⅞ × ⅞	5·47	10·90	16·40	21·90	27·30	32·30	38·30	43·90	49·40	54·70
2 × ¼	1·66	3·32	5·00	6·67	8·30	10·00	11·70	13·30	15·00	16·70
2 × ⅜	2·50	5·00	7·50	10·00	12·50	15·00	17·50	20·00	22·50	25·00
2 × ½	3·33	6·66	10·00	13·28	16·60	20·00	23·24	26·70	30·00	32·30
2 × ⅝	4·16	8·32	12·48	16·64	20·68	25·00	29·12	33·28	37·44	41·60
2 × ¾	5·00	10·00	15·00	20·00	25·00	30·00	35·00	40·00	45·00	50·00
2 × ⅞	5·82	11·64	17·46	23·28	29·10	35·00	40·74	46·56	52·50	58·30
2 × 1	6·67	13·30	20·00	26·60	33·25	40·00	46·55	53·40	60·00	66·70
2⅛ × ¼	1·76	3·52	5·28	7·04	8·80	10·60	12·40	14·20	15·90	17·70

2⅛ × ⅜	2·65	5·30	7·95	10·40	13·30	15·95	18·55	21·20	23·85	26·60
2⅛ × ½	3·53	7·06	10·59	14·12	17·59	21·30	24·80	28·30	31·90	35·30
2⅛ × ⅝	4·42	8·84	13·26	17·68	22·10	26·52	30·94	35·40	39·80	44·30
2⅛ × ¾	5·30	10·60	15·90	21·20	26·50	31·90	37·10	42·40	47·70	53·00
2⅛ × ⅞	6·20	12·40	18·60	24·80	31·00	37·20	43·40	49·60	55·80	62·00
2⅛ × 1	7·07	14·14	21·21	28·28	35·35	42·42	49·60	56·70	63·80	70·80
2¼ × ¼	1·87	3·74	5·63	7·50	9·35	11·30	13·09	14·96	16·83	18·80
2¼ × ⅜	2·80	5·60	8·40	11·30	14·10	16·90	19·70	22·50	25·20	28·00
2¼ × ½	3·74	7·48	11·22	14·96	18·70	22·44	26·18	29·92	33·80	37·50
2¼ × ⅝	4·68	9·36	14·04	18·72	23·40	28·08	32·76	37·44	42·12	46·90
2¼ × ¾	5·63	11·22	16·83	22·44	28·05	33·66	39·27	44·88	50·49	56·30
2¼ × ⅞	6·55	13·10	19·65	26·20	32·75	39·30	45·90	52·40	58·95	65·50
2¼ × 1	7·50	15·00	22·50	30·00	37·50	45·00	52·50	60·00	67·50	77·50
2⅜ × ¼	1·97	3·94	5·91	7·88	9·85	11·82	13·79	15·76	17·73	19·70
2⅜ × ⅜	2·96	5·92	8·88	11·84	14·80	17·76	20·72	23·80	26·64	29·60
2⅜ × ½	3·95	7·90	11·85	15·80	19·75	23·70	27·95	31·60	35·55	39·50
2⅜ × ⅝	4·94	9·88	14·82	19·76	24·70	29·64	34·58	39·52	44·46	49·40
2⅜ × ¾	5·92	11·84	17·76	23·68	29·60	35·52	41·44	47·36	53·28	59·20
2⅜ × ⅞	6·93	13·82	20·73	27·64	34·55	41·46	48·37	55·40	62·20	69·30
2⅜ × 1	7·92	15·80	23·80	31·70	39·60	47·50	55·40	63·30	71·30	79·20
2½ × ¼	2·08	4·16	6·24	8·32	10·40	12·48	14·56	16·64	18·72	20·80

Breadth and Thickness.	Weight in Pounds.									
	1 Foot.	2 Feet.	3 Feet.	4 Feet.	5 Feet.	6 Feet.	7 Feet.	8 Feet.	9 Feet.	10 Feet.
Inches.										
2½ × ⅜	3·12	6·24	9·36	12·48	15·60	18·80	21·90	25·00	28·10	31·20
2½ × ½	4·16	8·32	12·48	16·64	20·80	24·96	29·12	33·28	37·44	41·60
2½ × ⅝	5·20	10·40	15·60	20·80	26·00	31·20	36·40	41·60	46·80	52·00
2½ × ¾	6·24	12·48	18·72	24·96	31·20	37·50	43·80	50·00	56·30	62·40
2½ × ⅞	7·30	14·60	21·90	29·20	36·50	43·80	51·10	58·40	65·70	73·00
2½ × 1	8·35	16·70	25·05	33·40	41·75	50·10	58·45	66·80	75·00	83·50
2⅝ × ¼	2·18	4·36	6·54	8·72	10·90	13·08	15·26	17·50	19·70	21·80
2⅝ × ⅜	3·27	6·54	9·81	13·08	16·35	19·62	23·00	26·16	29·43	32·70
2⅝ × ½	4·36	8·75	13·08	17·44	21·80	26·30	30·60	35·00	39·40	43·60
2⅝ × ⅝	5·46	10·92	16·38	21·84	27·30	32·76	38·22	43·80	49·14	54·60
2⅝ × ¾	6·55	13·10	19·65	26·30	32·75	39·30	45·85	52·40	59·00	65·50
2⅝ × ⅞	7·64	15·28	22·92	30·56	38·20	45·84	53·48	61·12	68·76	76·40
2⅝ × 1	8·73	17·46	26·30	34·92	43·80	52·50	61·30	70·00	78·80	87·30
2¾ × ¼	2·28	4·56	6·84	9·12	11·50	13·68	15·96	18·24	20·52	22·80
2¾ × ⅜	3·43	6·86	10·29	13·72	17·15	20·58	24·01	27·44	30·90	34·30

2¾ × ½	4·57	9·14	13·71	18·28	22·85	27·42	32·00	36·56	41·13	45·70
2¾ × ⅝	5·72	11·44	17·16	22·88	28·60	34·32	40·10	45·76	51·60	57·20
2¾ × ¾	6·88	13·76	20·64	27·52	34·40	41·28	48·10	55·04	61·92	68·80
2¾ × ⅞	8·06	16·12	24·18	32·24	40·10	48·10	56·12	64·20	72·20	80·60
2¾ × 1	9·18	18·36	27·54	36·72	45·90	55·08	64·26	73·44	82·62	91·80
2⅞ × ¼	2·39	4·78	7·17	9·56	11·95	14·34	16·73	19·12	21·51	23·90
2⅞ × ⅜	3·58	7·16	10·74	14·32	17·90	21·60	25·20	28·80	32·30	35·80
2⅞ × ½	4·78	9·56	14·34	19·12	23·90	28·68	33·46	38·24	43·02	47·80
2⅞ × ⅝	5·99	12·00	18·00	24·00	30·00	36·00	42·00	48·00	54·00	60·00
2⅞ × ¾	7·19	14·40	21·60	28·80	36·00	43·10	50·30	57·50	64·70	71·90
2⅞ × ⅞	8·37	16·80	25·20	33·50	42·00	50·30	58·70	67·10	75·50	83·70
2⅞ × 1	9·58	19·20	28·80	38·30	48·00	57·50	67·10	76·70	86·30	95·80
3 × ¼	2·50	5·00	7·50	10·00	12·50	15·00	17·50	20·00	22·50	25·00
3 × ⅜	3·74	7·48	11·30	14·96	18·70	22·64	26·20	30·00	33·80	37·40
3 × ½	5·00	10·00	15·00	20·00	25·00	30·00	35·00	40·00	45·00	50·00
3 × ⅝	6·24	12·48	18·72	24·96	31·20	37·44	43·68	49·92	56·16	62·40
3 × ¾	7·50	15·00	22·50	30·00	37·50	45·00	52·50	60·00	67·50	75·00
3 × ⅞	8·73	17·46	26·30	34·92	43·65	52·38	61·11	70·00	78·80	87·30
3 × 1	10·00	20·00	30·00	40·00	50·00	60·00	70·00	80·00	90·00	100·00
3⅛ × ¼	2·60	5·20	7·80	10·40	13·00	15·60	18·20	20·80	23·40	26·00
3⅛ × ⅜	3·90	7·80	11·70	15·60	19·50	23·40	27·30	31·20	35·10	39·00

Breadth and Thickness.	Weight in Pounds.									
	1 Foot.	2 Feet.	3 Feet.	4 Feet.	5 Feet.	6 Feet.	7 Feet.	8 Feet.	9 Feet.	10 Feet.
Inches.										
3⅛ × ½	5·20	10·40	16·60	20·80	26·00	31·20	36·40	41·60	46·80	52·00
3⅛ × ⅝	6·50	13·00	19·50	26·00	32·50	39·00	45·50	52·00	59·50	65·00
3⅛ × ¾	7·80	15·60	23·40	31·20	39·00	46·80	54·60	62·40	70·20	78·00
3⅛ × ⅞	9·10	18 20	27·30	36·40	45·50	54·60	63·70	72·80	81·90	91·00
3⅛ × 1	10·40	20·80	31·20	41·60	52·00	62·40	72·80	83·20	93·60	104·00
3¼ × ¼	2·71	5·42	8·13	10·84	13·55	16·26	18·97	21·68	24·39	27·10
3¼ × ⅜	4·05	8·10	12·20	16·30	20·25	24·30	28·35	32·40	36·60	40·50
3¼ × ½	5·44	10·88	16·32	21·76	27·20	32·64	38·08	43·52	48·96	54·40
3¼ × ⅝	6·76	13·52	20·28	27·04	33·80	40·56	47·32	54·08	60·84	67·60
3¼ × ¾	8·14	16·28	24·42	32·56	40·70	48·84	56·98	65·12	73·26	81·40
3¼ × ⅞	9·46	18·92	28·38	37·94	47·40	56·76	66·22	75·88	85·14	94·60
3¼ × 1	10·82	21·64	32·46	43·28	54·10	64·92	75·74	86·56	97·38	108·20
3⅜ × ¼	2·80	5·60	8·40	11·20	14·00	16·80	19·60	22·40	25·20	28·00
3⅜ × ⅜	4·21	8·42	12·63	16·84	21·05	25·26	29·47	33·68	37·89	42·10
3⅜ × ½	5·62	11·24	16·86	22·58	28·10	33·72	39·34	44·96	49·58	56·20

3⅜ × ⅝	7·02	14·04	21·06	28·08	35·10	42·12	49·14	56·16	63·18	70·20
3⅜ × ¾	8·42	16·84	25·26	33·68	42·10	50·52	58·94	66·36	75·78	82·20
3⅜ × ⅞	9·82	19·64	29·46	39·28	49·10	58·92	68·64	78·56	88·38	98·20
3⅜ × 1	11·23	22·46	33·69	44·92	56·15	67·38	78·71	89·86	101·07	112·30
3½ × ¼	2·91	5·81	8·73	11·62	14·55	17·46	20·37	23·24	26·19	29·10
3½ × ⅜	4·37	8·74	13·11	17·48	21·85	26·22	30·59	34·96	39·33	43·70
3½ × ½	5·83	11·70	17·48	25·72	29·15	34·98	40·81	46·70	52·47	58·30
3½ × ⅝	7·28	14·56	21·84	29·12	36·50	43·68	50·96	58·24	65·52	72·80
3½ × ¾	8·74	17·48	26·22	34·96	43·70	52·44	61·18	69·92	78·66	87·40
3½ × ⅞	10·20	20·40	30·60	40·80	51·00	61·20	71·40	81·60	91·80	102·00
3½ × 1	11·70	23·30	34·95	46·60	58·30	69·90	81·70	93·30	105·00	117·50
3¾ × ¼	3·12	6·24	9·36	12·48	15·60	18·72	21·84	24·96	28·08	31·20
3¾ × ⅜	4·68	9·36	14·04	18·72	23·40	28·08	32·76	37·44	42·12	46·80
3¾ × ½	6·24	12·48	18·72	24·96	31·20	37·44	43·68	49·92	56·16	62·40
3¾ × ⅝	7·80	15·60	23·40	31·20	39·40	46·80	54·60	62·40	70·20	78·80
3¾ × ¾	9·36	18·72	28·08	37·44	46·90	56·30	65·60	75·00	84·24	93·60
3¾ × ⅞	10·92	21·84	32·76	43·80	54·60	65·52	76·44	87·36	98·28	109·20
3¾ × 1	12·50	25·00	37·50	50·00	62·50	75·00	87·50	100·00	112·50	125·00
4 × ¼	3·33	6·66	10·00	13·30	16·70	20·00	23·30	26·70	30·00	33·30
4 × ⅜	5·00	10·00	15·00	20·00	25·00	30·00	35·00	40·00	45·00	50·00
4 × ½	6·67	13·33	20·00	26·72	33·40	40·08	46·76	53·44	60·12	66·70

Breadth and Thickness.	Weight in Pounds.									
	1 Foot.	2 Feet.	3 Feet.	4 Feet.	5 Feet.	6 Feet.	7 Feet.	8 Feet.	9 Feet.	10 Feet.
Inches.										
4 × 5/8	8·32	16·70	25·00	33·30	41·70	50·00	58·30	66·70	75·00	83·20
4 × 3/4	10·00	20·00	30·00	40·00	50·00	60·00	70·00	80·00	90·00	100·00
4 × 7/8	11·70	23·30	35·00	46·70	58·40	70·00	81·70	93·30	105·00	116·80
4 × 1	13·31	26·62	40·00	53·30	66·70	80·00	93·30	106·70	120·00	133·40
4¼ × 1/4	3·54	7·08	10·62	14·16	17·70	21·30	24·80	28·32	31·86	35·40
4¼ × 3/8	5·30	10·60	15·90	21·30	26·60	31·90	37·20	42·50	47·80	53·20
4¼ × 1/2	7·09	14·18	21·27	28·36	35·45	42·54	49·63	56·72	63·81	70·90
4¼ × 5/8	8·84	17·68	26·54	35·40	44·30	53·10	62·00	70·80	79·70	88·40
4¼ × 3/4	10·60	21·30	31·90	42·40	53·10	63·80	74·40	85·00	95·60	106·00
4¼ × 7/8	12·38	24·76	37·14	49·60	62·00	74·40	86·80	99·20	111·60	123·80
4¼ × 1	14·15	28·30	42·45	56·60	70·80	84·90	99·20	113·30	127·50	141·50
4½ × 1/4	3·75	7·50	11·25	15·00	18·75	22·50	26·25	30·00	33·79	37·50
4½ × 1/2	7·50	15·00	22·50	30·00	37·50	45·00	52·50	60·00	67·50	75·00
4½ × 3/4	11·24	22·48	33·72	44·96	56·20	67·44	78·68	90·00	101·16	112·40
4½ × 1	15·00	30·00	45·00	60·00	75·00	90·00	105·00	120·00	135·00	150·00

5 × ¼	4·16	8·32	12·48	16·64	20·80	24·96	29·12	33·28	37·44	41·60
5 × ½	8·32	16·64	24·96	33·28	41·70	49·92	58·30	66·70	75·00	83·20
5 × ¾	12·49	25·00	37·47	50·00	62·45	75·00	87·43	100·00	112·41	124·90
5 × 1	16·66	33·32	50·00	66·64	83·30	100·00	116·62	133·28	150·00	166·60
5¼ × ¼	4·37	8·74	13·11	17·48	21·85	26·22	30·59	35·00	39·40	43·70
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